A Critical Evaluation of the Nonradiological Environmental Technical Specifications

Vol. 1 Program Description, Summary, and Recommendations

S. M. Adams
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K. D. Kumar
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Prepared for the U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
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OAK RIDGE NATIONAL LABORATORY

OPERATED BY UNION CARBIDE CORPORATION FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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ENERGY DIVISION

A CRITICAL EVALUATION OF THE NONRADIOLOGICAL
ENVIRONMENTAL TECHNICAL SPECIFICATIONS

Vol. 1: PROGRAM DESCRIPTION, SUMMARY, AND RECOMMENDATIONS

S. M. Adams*
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FOREWORD

Under the sponsorship of the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory Commission, Argonne National Laboratory, Battelle Northwest Laboratory, and Oak Ridge National Laboratory have collaborated in conducting a one-year study on the evaluation of the nonradiological environmental monitoring programs and Technical Specifications requirements at various operating nuclear power plants. As a result of this work, a series of reports is being prepared by the three laboratories. The titles of these reports are given below.

Argonne National Laboratory

The following reports were prepared by Argonne National Laboratory scientists:

<u>Report Title</u>	<u>Report Number</u>
An Evaluation of Environmental Data Relating to the Kewaunee Nuclear Power Plant Site	ANL/EIS-1
An Evaluation of Environmental Data Relating to the Quad Cities Nuclear Power Station	ANL/EIS-2
An Evaluation of Environmental Data Relating to the Duane Arnold Energy Center	ANL/EIS-3
An Evaluation of Environmental Data Relating to the Three Mile Island Site	ANL/EIS-4
An Evaluation of Environmental Data Relating to the Zion Nuclear Power Plant	ANL/EIS-5
An Evaluation of Environmental Data Relating to the Prairie Island Site	ANL/EIS-6
An Evaluation of Environmental Data Relating to the Nine Mile Point - 1	ANL/EIS-7
An Evaluation of Environmental Data Conclusions and Recommendations for Nonradiological Environmental Monitoring	ANL/EIS-8

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Battelle Northwest Laboratory

The following reports were prepared by Battelle Northwest Laboratory scientists:

<u>Report Title</u>	<u>Report Number</u>
Evaluation of Monticello Nuclear Power Plant Environmental Impact Prediction, Based on Monitoring Program	BNWL-1250
Evaluation of Haddam Neck (Connecticut Yankee) Nuclear Power Plant Environmental Impact Prediction, Based on Monitoring Program	BNWL-1251
Evaluation of Millstone Nuclear Power Plant, Unit 1, Environmental Impact Prediction, Based on Monitoring Program	BNWL-1252
Evaluation of Three Nuclear Power Plants, Environmental Prediction, Based on Monitoring Program. A Summary Report	BNWL-1253

Oak Ridge National Laboratory

The following reports were prepared by Oak Ridge National Laboratory scientists:

<u>Report Title</u>	<u>Report Number</u>
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: Conclusions and Recommendations	ORNL/NUREG/TM-69
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: Surry Power Plant Units 1 and 2	ORNL/NUREG/TM-70
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: Peach Bottom Atomic Power Station Units 2 and 3	ORNL/NUREG/TM-71
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: San Onofre Nuclear Generating Station Unit 1	ORNL/NUREG/TM-72

ABSTRACT

A comprehensive study of the data collected as part of the environmental Technical Specifications program for eight nuclear power plants was conducted for the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory Commission. This report includes a summary of the screening phase in which the adequacy of the hydrothermal and ecological monitoring data for each plant were evaluated, and the summary and recommendations resulting from a detailed examination of the three nuclear power plants selected in the initial screening.

1. Several power plants in the study were eliminated from consideration for more in-depth analysis because their operating histories were sporadic. In several cases, one or more reactors at a site were shut down for extensive periods or the cooling mode was modified from once-through cooling to cooling towers during a long retrofitting period. In addition, at least one year of operational data, including both ecological and hydrothermal monitoring, was needed for our evaluation. After this initial phase was completed, Surry, Peach Bottom, and San Onofre were selected as the three representative facilities for in-depth analysis. The in-depth analysis of the three plants was performed to determine whether (1) the individual monitoring programs conformed to the intent of the Appendix B requirements, (2) the monitoring programs were adequate to detect specific environmental impacts, (3) a significant impact had occurred related to plant-induced perturbations, and (4) sampling changes could be suggested in light of the recent advances in impact analysis.
2. Results of this Technical Specifications review study will ultimately feed back into the present environmental assessment process and provide a better basis for predicting potential impacts at future facilities. The second phase of the review program involved making final recommendations on the overall process based on problems encountered in the analysis process. General considerations in implementing a sampling policy are discussed, including procedures for sample size calculations. Final recommendations for hydrothermal monitoring were made after considering the usefulness of fixed thermograph networks, infrared imaging, and boat surveys.
3. Fixed thermograph networks were considered to provide the best method for ensuring continuous environmental surveillance and for constructing probabilistic isotherm maps to assess which regions in the discharge area are located within a specific excess temperature isotherm for a specific percent of the time. Thermograph data may best be supplemented by infrared imaging, which provides a means for studying the configuration of the plume at a given instant. Infrared imaging is unique in its ability to describe impingement of the plume on beaches and swampy areas where other monitoring is impractical. Boat surveys have several drawbacks, particularly if the plume is large, because significant changes in the plume configuration may occur in the time needed for the boat to traverse the plume. Final

recommendations for modernizing ecological monitoring programs stress the need for designing sampling regimes in light of the unique site-specific considerations, intensively monitoring in both a preoperational and an operational period, and monitoring all trophic levels important in a particular ecosystem.

4. Proper selection of monitoring stations during the preoperational period should involve identification of monitoring areas with comparable physical characteristics (i.e., velocity of current, depth, and bottom sediment type) and chemical characteristics (i.e., salinity, pH, and dissolved oxygen), which directly affect the type of biological community within the area. Standardized methods for collection of biota at all facilities should be encouraged so that comparisons could be made among various power plants situated in similar ecological habitats. In addition, standardized reporting formats and methods of analysis of data should be established to facilitate evaluation of monitoring results. Recommendations are directed toward re-evaluating Technical Specifications at existing nuclear facilities and suggestions of new techniques for Technical Specifications at new facilities in light of knowledge and experience gained from the study of operating facilities.

CONTENTS - VOLUME 1

	<u>Page</u>
I. INTRODUCTION	1-1
II. PRELIMINARY ASSESSMENT OF CANDIDATE MONITORING PROGRAMS	1-10
A. PEACH BOTTOM	1-10
B. SURRY	1-13
C. OCONEE	1-16
D. SAN ONOFRE	1-18
E. PALISADES	1-21
F. GINNA	1-23
G. VERMONT YANKEE	1-25
H. ARKANSAS	1-28
III. RECOMMENDATIONS FOR SAMPLING POLICIES	1-30
A. GENERAL CONSIDERATIONS IN SAMPLING POLICY	1-30
B. GENERAL CONSIDERATIONS IN THE DESIGN OF ECOLOGICAL MONITORING PROGRAMS	1-30
1. Monitoring program design	1-31
2. Methodology for sample size calculations	1-33
3. Conclusions	1-36
C. RECOMMENDATIONS FOR TECHNICAL SPECIFICATIONS	1-36
1. Hydrothermal monitoring	1-36
2. Ecological monitoring	1-39
REFERENCES	1-46

LIST OF TABLES - VOLUME 1

<u>Table</u>	<u>Page</u>
1.1 Operating reactors with environmental statements prepared by the staff of Oak Ridge National Laboratory for consideration for Technical Specification research	1-3
1.2 Annual power plant capacity factor (percent)	1-4
1.3a Summary of readily available hydrothermal monitoring data	1-5
1.3b Summary of readily available hydrothermal monitoring data -- temperature monitoring	1-6
1.3c Summary of readily available hydrothermal monitoring data -- temperature monitoring	1-7
1.4 Overall ranking of plants	1-8
1.5a Summary of readily available ecological monitoring data	1-8
1.5b Summary of readily available ecological monitoring data	1-9
1.5c Summary of readily available ecological monitoring data	1-9
1.6 Analysis of variance for chlorophyll a data collected during a 14-day period	1-34
1.7 Cost functions (L) for various combinations of number of sampling days (n) and number of replicates per day (k) . . .	1-35

I. INTRODUCTION

The first part of this report summarizes the screening phase of the nonradiological environmental Technical Specifications review program conducted by Oak Ridge National Laboratory (ORNL). The second part of the report contains final generic recommendations for environmental Technical Specifications based on a detailed review of three operating reactors. The screening phase was completed in December 1975, and the final recommendations were drafted in November 1976.

Nonradiological environmental Technical Specifications are contained in Appendix B of the Operating License of a nuclear power plant. These requirements are intended to limit operating parameters (i.e., discharge temperature and chlorine effluents) that might directly impact the environment and to provide guidelines for monitoring aquatic and terrestrial impacts at the site. Because the environmental phenomena of interest vary from site to site, no two power plants have identical environmental Technical Specifications.

In the past, very broad monitoring programs were often required to compensate for the primitive state-of-the-art in environmental impact prediction and the lack of experience with large nuclear power plants. Now, operating experience is rapidly being documented in monitoring reports, and the time has come to evaluate this approach to environmental protection. The Technical Specifications review program was initiated to examine the hydrothermal and ecological monitoring data and to determine whether:

1. present monitoring programs conform to the Appendix B requirements;
2. present monitoring programs are adequate to detect or quantify specific environmental impacts;
3. a significant impact has occurred that is related to power plant operations; and
4. sampling changes could be suggested in light of the above considerations and the recent advances in impact analysis.

The answers to these questions are of great importance from environmental and economic viewpoints. If the monitoring data are adequate for the assessment of impacts, this will ensure the identification of ecological problems at a given site. If data are inadequate, revision of the monitoring programs must be initiated so that suspected impacts can be measured without further delay. From the economic point of view, considerable savings may result if specific environmental parameters are shown to be unaffected by plant operations (after intensive monitoring) because monitoring programs might then be reduced.

In the initial phase of the study, the ORNL staff reviewed both hydrothermal and ecological monitoring programs of eight nuclear power plants for which Final Environmental Statements (FESs) were prepared at ORNL.

These eight power plants and some of their pertinent operating characteristics are listed in Table 1.1. Only those plants with at least one year of operating time were considered. The annual plant capacity factor for each plant is given in Table 1.2. This parameter provides an indication of the amount of time a given reactor was actually in operation. The relatively short operating life of most of the power plants made assessment of plant-induced perturbations difficult to distinguish from natural variations. The task was further complicated by the very irregular patterns of power production which frequently occur in the first few years of plant operation. Many of the important features of the hydrothermal monitoring programs considered in this evaluation are listed in Table 1.3. In Table 1.4, the overall quality of the various hydrothermal monitoring programs have been ranked based on the preliminary review completed in December 1975.

The ecological monitoring programs for each plant are summarized in Table 1.5 with respect to the sampling programs employed to determine the effects of thermal effluents on the major aquatic trophic groups, impingement, entrainment, and the use of biocides and heavy metals. These various ecological monitoring programs are ranked in Table 1.4 based on overall comprehensiveness of the monitoring programs and on adequacy of the data for use in assessing the validity of impact prediction and formulation of predictive models.

Following the preliminary screening based primarily on the adequacy of the monitoring programs and the length of operation of each plant, the authors derived the overall composite rankings, which are listed in Table 1.4. The authors selected San Onofre, Surry, and Peach Bottom as the most promising candidates to be reviewed in detail.

In the second phase of the Technical Specifications review program, attention was focused on the three plants having the best data for analysis in an attempt to address specific concerns about the adequacy of the Technical Specifications. An evaluation of each plant considers thermal plume configuration, thermal stress on biota, impingement of fish on intake screens, entrainment of planktonic biota into the plant, and effects of chemical discharges. Consideration of these issues in different environmental settings (Volumes 2, 3, and 4) may aid in synthesizing common problems and contribute to advancing the state-of-the-art of environmental impact prediction. Overall recommendations resulting from this review of the Technical Specifications program are presented in the second half of this volume.

Table 1.1. Operating reactors with environmental statements prepared by the staff of Oak Ridge National Laboratory for consideration for Technical Specification research

Power plant	Date of commercial operation	Cooling system	Discharge structure	Location	Power (MW(e))	ΔT
Peach Bottom 2	5/74	Once-through cooling and mechanical draft towers	Surface canal with sluice gate	Susquehanna River, Pa. (Conowingo Pond)	1100	13°F to 18°F
Peach Bottom 3	12/74	Once-through cooling and mechanical draft towers	Surface canal with sluice gate	Susquehanna River, Pa. (Conowingo Pond)	1100	13°F to 18°F
Surry 1	12/72	Once-through cooling	Surface canal	James River, Va. (estuary)	820	14°F
Surry 2	5/73	Once-through cooling	Surface canal	James River, Va. (estuary)	820	14°F
Oconee 1	7/73	Once-through cooling	Submerged slot	Lake Keowee, S.C.	847	19°F
Oconee 2	9/74	Once-through cooling	Submerged slot	Lake Keowee, S.C.	886	19°F
Oconee 3	12/74	Once-through cooling	Submerged slot	Lake Keowee, S.C.	886	19°F
San Onofre 1	1/68	Once-through cooling	Single port vertical discharge	Pacific Ocean, Calif.	430	19°F
Palisades	1/72	Once-through cooling through 1973; mechanical draft towers since 1974	Surface canal	Lake Michigan, Mich.	700	28°F (with towers 5°F)
Genoa	3/70	Once-through cooling	Surface canal	Lake Ontario, N.Y.	486	18.4°F
Vermont Yankee	11/72	Once-through cooling and mechanical draft towers	Surface canal	Connecticut River, Vt.	514	Above 70°F ambient = no thermal discharge; 67°F to 70°F = 1°F in river; 55°F to 67°F = intermediate °F rise; below 55°F 5°F rise in river
Arkansas 1	12/74	Once-through cooling	Surface canal	Dardanelle Res., Ark.	820	15°F

Table 1.2. Annual power plant capacity factor (percent)^{a,b}

Power plant	Date of initial criticality	Date of commercial operation	1967	1968	1969	1970	1971	1972	1973	1974	First half of 1975
San Onofre 1	6/67	1/68	21	34	69	81	88	75	60	84	73
Ginna	11/69	3/70			20	58	66	64	87	52	50
Palisades	5/71	1/72						57	41	1	29
Vermont Yankee	3/72	11/72						38	44	56	83
Surry 1	7/72	12/72						47	57	50	68
Surry 2	3/73	5/73							73	40	61
Oconee 1	4/73	7/73							57	52	51
Oconee 2	11/73	9/74								58	57
Oconee 3	9/74	12/74								42	51
Arkansas 1	8/74	12/74								65	56
Peach Bottom 2	9/73	5/74								82	66
Peach Bottom 3	8/74	12/74								77	61

^aPower plant capacity factor = $\frac{\text{Net electric energy generated} \times 100}{\text{"Maximum dependable capacity"} \times \text{Gross hours in reporting period}}$

"Maximum dependable capacity" is sometimes replaced by "Current licensed power level" or "Authorized MW(e) (net)"

^bData taken from *Operating History of U.S. Nuclear Reactors 1974*, ERDA-29-74, and from *Operating Plants Status Reports*, NUREG-75/020-1 through NUREG-75/020-12.

Table 1.3a. Summary of readily available hydrothermal monitoring data

Power plant	Operating data			Meteorological data					Ambient water level	Temperature monitoring		
	Power	Flow rate	ΔT	Dry-bulb	Wet-bulb	Wind speed	Wind direction	Cloud cover		Number of stations	Fixed stations Number of depths per station	Frequency
Peach Bottom	C ^a	C		D ^b	D	D	DBS ^c	DBS	DBS	18	1	H ^d
Surry	C			DBS		DBS	DBS	DBS		7	2	C
Oconee	C	C	C	M ^e						3/14	10	C/M
San Onofre						C	C			2	3	0.5 hr
Palisades	C		C	DBS		DBS	DBS			-		
Ginna	C			DBS		DBS	DBS	DBS		-		
Vt. Yankee	C									2	1	H
Arkansas										-		

^aC = continuous.

^bD = daily.

^cDBS = during boat surveys.

^dH = hourly.

^eM = monthly.

Table 1.3b. Summary of readily available hydrothermal monitoring data - temperature monitoring

Power plant	Number of stations	Boat survey			Airborne survey frequency	Graphical presentations			
		Number of depths per station	Frequency	Elapsed time		Horizontal isotherms	Vertical cross sections		
						Number of depths	Frequency	Number of sections	Frequency
Peach Bottom	74	3	1 to 23 per month	5 hr		3	1 to 23 per month	1	1 to 23 per month
Surry	C ^a	3	40/year	2 hr	2/year	1	40/year		
Oconee	30	15	Q ^b	8 hr				1/1	M ^c /Q
San Onofre	30	C	6/year	9 hr	4/year	1	6/year	1	6/year
Palisades	70/20	1/10	12/year		1	1	12/year		
Ginna	C	4	M	3 hr		4	M		
Vermont Yankee									
Arkansas									

^aC = continuous.^bQ = quarterly.^cM = monthly.

Table 1.3c. Summary of readily available hydrothermal monitoring data — temperature monitoring^a

Power plant	Graphical presentations				Area within isotherms	Velocity data	Salinity data
	Vertical profiles		Time history				
	Number of stations	Frequency	Number of stations	Number of depths			
Peach Bottom			2	1	X		
Surry	7	(averaged)	7	2	X		X
Oconee	3	M ^b					
San Onofre	30	6/year	2	1	X		X
Palisades	40 to 20	12/year					
Ginna							
Vermont Yankee							
Arkansas							

^aData available as of December 1975.

^bM = monthly.

Table 1.4. Overall ranking of plants

Power plant	Operating history (years) ^a	Quality of hydrothermal monitoring	Quality of ecological monitoring			Overall
			Thermal (biological)	Impingement	Entrainment	
Peach Bottom	1.5	1	1	3	2	1
Surry	3	3	4	1	1	2
San Onofre	8	2	2	5	Pending	3
Oconee	2.5	6	3	4	3	4
Palisades	1.75	5	5	7	4	5
Vermont Yankee	3	7	6	None	5	6
Genoa	6	4	None	2	None	7
Arkansas	1	None	None	6	None	8

^aThrough December 1975.Table 1.5a. Summary of readily available ecological monitoring data
BIOLOGICAL ANALYSIS - ZOOPLANKTON AND PHYTOPLANKTON

Power plant	ZOOPLANKTON						PHYTOPLANKTON									
	Species composition	Density	Diversity	Ichthyoplankton	Entrainment model ^a	Percent survivorship	Composition taxonomic species	Density	Diversity	Phytopigments				Phaeopigments	Carotenoids	¹⁴ C primary productivity
										Chlorophyll A (total)	Chlorophyll A (active)	Chlorophyll B	Chlorophyll C			
Peach Bottom	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Surry	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Oconee	•	•	•	•	NA ^b	•	•	•	•	•	•	•	•	•	•	•
San Onofre	•	•	•	•	NA ^b	•	•	•	•	•	•	•	•	•	•	•
Palisades	•	•	•	•	NA ^b	•	•	•	•	•	•	•	•	•	•	•
Genoa	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Vermont Yankee	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Arkansas	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

^aIncluded in calculation of entrainment model are river flow and pumping rate of plant.^bDoes not apply (static system).

Table 1.5b. Summary of readily available ecological monitoring data
BIOLOGICAL ANALYSIS – NEKTON AND ABIOTIC FACTORS

Power plant	NEKTON										ABIOTIC FACTORS			
	Sampling methods ^a								Impingement			Bioicides (chlorine)	Heavy metals	Turbidity
	Rotenone	Electrofishing	Seining	Trawl	Trap net	Fish wheel	Gill net	Underwater camera	Diversity	Model				
										Factor ^b	Ecological	Percent survivors ^c		
Peach Bottom			•	•	•				•	•		•	•	•
Surry			•	•		•			•	•	•		•	•
Oconee	•	•	•	•			•	•	•	•		•		•
San Onofre							•		•	•		•	•	•
Paisades			•	•			•		•	•		•		•
Ginna									•	•				
Vermont Yankee			•		•		•			•			•	•
Arkansas										•				

^aMethods used to estimate fish abundances.

^bFactor model refers to identifying those parameters that influence impingement such as temperature, pumping rate of plant, behavior of fish, size distribution of fish, and thigmotrophic responses.

^cEcological model requires knowledge of population dynamics and abundance of all fish species

Table 1.5c. Summary of readily available ecological monitoring data
BIOLOGICAL ANALYSIS – BENTHOS AND FOULING ORGANISMS

[illegible]

II. PRELIMINARY ASSESSMENT OF CANDIDATE MONITORING PROGRAMS

In this section, the nonradiological environmental monitoring programs of the candidate power plants are described and evaluated. The candidate power plants are those whose Final Environmental Statements (FESs) were written by GRNL and those that have operated for one year or more as of December 1975. Each power plant is treated in turn, and the following topical outline adopted for the program is followed.

I. Plant Design and Characteristics

II. Plant Site Characteristics

III. Operating History

IV. Preliminary Assessment

- A. Hydrothermal monitoring
- B. Ecological evaluation
 - 1. Thermal effects
 - 2. Impingement
 - 3. Entrainment
- C. Chemical effluents
- D. Avian mortality
 - 1. Cooling towers
 - 2. Transmission lines
- E. Salt drift
- F. Herbicides

A. PEACH BOTTOM

Plant Design and Characteristics

The two units of the Peach Bottom Atomic Power Station, Units 2 and 3, consist of two boiling-water reactors (BWRs), each producing 1100 MW(e) of power (Table 1.1). Cooling water for both systems (winter and summer) is withdrawn directly from Conowingo Pond through an intake portal that is 487 ft long with 32 intake openings that are protected by vertical trash bars. Behind the trash bars are 24 vertical traveling screens. Waste heat is dissipated by once-through cooling of the condensers directed into an intermediate cooling pond (400 ft by 700 ft), from which the effluent is directed down a 4700-ft canal (300 to 400 ft wide) to a submerged discharge port emptying into Conowingo Pond. During operation, 53% of the water is diverted through mechanical-draft helper cooling towers (open cycle) for preliminary cooling before subsequent discharge to the canal and reservoir. The ΔT during operation ranges from 13°F to 18°F, depending on the weather.

Plant Site Characteristics

The Peach Bottom Atomic Power Station is located on Conowingo Pond, a mainstream freshwater impoundment between the Holtwood and Conowingo Dams on the lower Susquehanna River in southeastern Pennsylvania. Conowingo Pond has more aspects of a lake than a river, being 12 to 20 ft deep at the northern upriver portion and reaching a depth of 90 ft at the Conowingo Dam. Water movements within the pond are complex because of variable inflows from the Holtwood Hydroelectric Plant and the Muddy Run Pumped Storage Station and outflows through Conowingo Dam.

Operating History

As of January 1976, Peach Bottom Unit 2 had about 18 months of commercial operating experience. Unit 3 had been in commercial operation for about 1 year (see Table 1.2 for additional details).

Preliminary Assessment

Hydrothermal monitoring. Peach Bottom is located in an environment that is conducive to thorough hydrothermal monitoring. Conowingo Pond is completely regulated, and its geometry is relatively simple. The inflows and outflows of Conowingo Pond are complex but well-known. The design of the cooling system and discharge structure is somewhat atypical. As mentioned above, the plant is a hybrid using once-through cooling with helper towers, and the heated effluent discharges under a sluice gate parallel to the shore.

The Peach Bottom thermal monitoring program has been very complete, especially since July 1974 (Table 1.3). The data presentation in the monthly reports is particularly useful. The best feature of the Peach Bottom monitoring program has been the successful network of continuously operating thermographs. The main drawbacks of this program are the lack of velocity data and the long time necessary to complete the boat surveys. These typically last 5 hr, and thus do not give an instantaneous picture of the plume.

Ecological evaluation. Ecological evaluations were made on the thermal effects of the plant on phytoplankton, zooplankton, benthos, and fish and on the impingement and entrainment effects of the plant.

1. Thermal effects. Concentrations of chlorophyll *a* (active and total), chlorophyll *b*, chlorophyll *c*, phaeopigments, and carotenoids (sampled biweekly) were used in monitoring the primary producers. No enumeration or identification of major phytoplankton genera was performed (see Table 1.5). Zooplankton were collected biweekly with a Clarke-Bumpus sampler. Data were reported as number of organisms per liter and as milligrams (dry weight) per liter for zooplankton taxa at 11 discharge and control stations. Benthic samples were collected with

an 81-in.² dredge at 11 stations in Conowingo Pond. Data were presented as numbers and dry weights for major species at each station. Species diversity and similar indices were calculated for each station. Changes in sieve-pore sizes and dredge types made comparison of preoperational and operational data impossible. Nekton were sampled with meter nets, trap nets, trawls, and seines at various transects and zones within Conowingo Pond. Control and discharge stations have been consistently sampled from 1967 to the present. Data were presented as catch per unit effort (employing various types of gear) for each species at both control and discharge stations. Laboratory temperature experiments on temperature preference and avoidance, cold shock, and swimming speeds have been performed for the major species.

2. Impingement. Impinged fish were sampled weekly during two consecutive 12-hr periods. Data were presented as total number and total weight of each species impinged, fork-length range (millimeters), mean fork length (millimeters), and biovolume (cubic feet). Supporting data include mean number of pumps operating, mean pond elevation, daily river flow, intake temperature, and time of day.
3. Entrainment. Entrainment mortality of zooplankton was determined from biweekly samples collected from January to June and at weekly intervals using vital staining procedures beginning in June. Estimates of mortality were presented for the major groups and species of zooplankton.

Chemical effluents. The semiannual report for Peach Bottom contained monitoring data on concentrations of copper, zinc, cadmium, iron, cobalt, nickel, chromium, and manganese, including the mean, maximum, and minimum monthly values. Suspended solids (milligrams per liter), nitrites, nitrates, total phosphates, and pH were also measured.

Chlorine was sampled inconsistently on a daily basis, but concentrations were generally less than 0.5 ppm.

Avian mortality. Avian mortality was considered for the impact of both cooling towers and transmission lines.

1. Cooling towers. At Peach Bottom, heat is dissipated by both once-through cooling and three mechanical-draft cooling towers (53 ft high). No monitoring data on bird populations are required by the Technical Specifications.
2. Transmission lines. Only one 500-kV transmission line was required to integrate Peach Bottom to the applicant's bulk power system. No prediction of environmental impact is made, although the Susquehanna River basin is a major flyway used by many species of waterfowl including Canada goose, black duck, mallard, and scaup. No monitoring data are required by Technical Specifications for transmission lines.

Salt drift. The utility expects actual drift loss to be 450 to 850 gpm. Normal wind patterns at the plant site carry the majority of drift over Conowingo Pond. No monitoring data on salt drift are required by the Technical Specifications.

Herbicides. No herbicides were employed, except in the following cases:

1. In clearing areas containing flush cut stumps of trees and scrubs, a 4% solution of a mixture containing equal parts 2,4,D and 2,4,5-T was employed.
2. When necessary, an Amchem growth retardant (NAI-10637 + 1% NAA + 1% ethyl alpha-naphthlene acetate) was applied to fresh cuts of trimmed trees.
3. When right-of-way access for maintenance is difficult, growth is controlled by a mixture of Tordon #155 (Dow Chemical) and fuel oil.

No monitoring data on herbicide use at the Peach Bottom site were required in the Technical Specifications.

B. SURRY

Plant Design and Characteristics

The Surry Power Station has two units (Units 1 and 2), each with a pressurized-water reactor (PWR) designed to produce 820 MW(e) power (Table 1.1). Waste heat during full-power operation of both units is dissipated by once-through cooling. Cooling water is withdrawn from the James River through a 150-ft-wide x 5000-ft-long x 13-ft-deep channel dredged into the river bed between the main river channel and the shore. The reinforced concrete intake (with trash racks) was originally equipped with an air bubble system for diverting fish away from cooling water pumps, but this has been replaced with Ristolph traveling screens. Thermal effluent water ($\Delta T = 14^{\circ}\text{F}$) is discharged through a 2900-ft-long surface discharge canal. The surface canal discharges into the James River upstream of the intake at about 6 fps.

Plant Site Characteristics

The Surry Power Station is located on the James River Estuary (centered at Hog Island) in Virginia. This tidal estuary creates a brackish water environment (salinity range from 0 to 18 ppt) where portions of the shoreline are composed of swamps and marshes. In comparison to total tidal flows, fresh river-water flows are far lower. When river flow is low (less than 10,000 cfs), salt water extends upstream of the Surry discharge canal, and the entire Hog Point region can be characterized as a partially mixed estuary, with salinity fluctuation occurring in a regular manner.

Operating History

As of January 1976, Surry 1 had almost three years while Surry 2 had been on line for 2.5 years (Table 1.2).

Preliminary Assessment

Hydrothermal monitoring. Surry lies in an S-shaped region of the James River tidal estuary. This is probably the most complex hydrothermal setting of any plant considered in this study. Surry's plume swings back and forth with the tide and sometimes sinks because the intake water is of higher salinity than the ambient water near the discharge site. These factors limit the general applicability of the Surry experience, which is unfortunate because the thermal monitoring program conducted by the Virginia Institute of Marine Sciences had many good features (see Table 1.3). Sophisticated instrumentation allowed continuous temperature measurement from a fast boat. The entire boat survey generally lasts less than 2 hr, a big advantage compared to some other studies. There have also been studies involving airborne infrared temperature surveys, salinity measurements, and measurements from drogues carried along in the plume.

Ecological evaluation. Ecological evaluations were made on the thermal effects of the plant on phytoplankton, zooplankton, benthos, and fish and on the impingement and entrainment effects of the plant.

1. Thermal effects. Duplicate phytoplankton samples were collected monthly beginning in January 1973 using a 2-liter Van Dorn bottle. Replicate chlorophyll *a* concentrations and primary productivity measurements (using ^{14}C) were also taken monthly at each station. Major phytoplankton genera were identified, but no quantitative enumeration is presented (Table 1.5). Two monthly surface zooplankton samples have been collected since June 1972 with a 12.5-cm Clarke-Bumpus sampler (#20 mesh). Replicate 0.05-m² ponar grab samples were collected quarterly except for June, July, and August, when samples were collected monthly. The attached benthic community was monitored by two horizontal and two vertical fouling plates suspended 1 m above the bottom at two different locations. One of each pair was removed and replaced quarterly; the other pair was removed after one year and analyzed for species composition and diversity. Monthly and weekly fish surveys have been conducted since 1970 in various transects. Fishes in the inshore zone were sampled with haul seines, and shallow water fishes were sampled with otter trawls. Ichthyoplankton were also sampled in connection with entrainment studies.
2. Impingement. Fish impingement estimates for the high-level screens were based on four 5-min replicates per unit, taken five times per week during daylight and three times per week at night. The low-level screens (Ristolph traveling screens) were monitored five days

a week with two 5-min replicates per day. Data were reported by species, number impinged, and modal size (millimeters). Additional pertinent data, including minimum and maximum temperatures and salinities, daily river flow, and the number of circulating pumps operating, were given.

3. Entrainment. Preliminary estimates of mortality due to entrainment of zooplankton (copepods, cladocerans, decapod larvae, and amphipods) and ichthyoplankton were calculated by three methods: (1) differentiation of stained and unstained organisms at the discharges, (2) differences in living organisms in the intake and discharge, and (3) differences in living organisms between the intake and discharge (corrected for dead organisms in the intake). Differential mortality due to thermal and mechanical effects are discussed.

Chemical effluents. No chemical additions were made to the condenser cooling water because mechanical methods of cleaning turbines were used (Amertap).

Mean monthly values for suspended solids (parts per million), pH, and total phosphate were made, and the monthly maximum and minimum values were given.

Avian mortality. Avian mortality was considered for the impact of both cooling towers and transmission lines.

1. Cooling towers. Heated effluent water is dissipated by once-through cooling.
2. Transmission lines. Eleven miles of new transmission lines were needed to connect Surry to various substations. A portion of the adjacent lands (Hog Island State Waterfowl Refuge) was drained and seeded to increase waterfowl utilization. Both resident and migrating populations are supported in the refuge, with peak populations exceeding 25,000. No monitoring data on bird populations are required by the Technical Specifications.

Salt drift. Condenser heat is dissipated by once-through cooling.

Herbicides. The applicant has cleared 3543 acres of all timber and brush in the transmission rights-of-way, and the corridors are maintained free of woody growth either through seeding or chemical treatment every three years. The following herbicides are used: Tordon 101 for pines (resistant species), Silnex for oaks (intermediate species), and 2,4,5,T for broadleaf species. No monitoring data are required in the Technical Specifications for herbicide impacts.

C. OCONEE

Plant Design and Characteristics

The three units (Units 1, 2, and 3) of the Oconee Nuclear Station consist of pressurized-water reactors (PWRs) designed to produce 847, 886, and 886 MW(e) respectively. Waste heat is dissipated by once-through cooling of the condenser (Table 1.1). Cooling water is withdrawn from the Little River arm of Lake Keowee into an intake canal. Across the canal mouth is a skimmer wall to divert cooler bottom water into the intake. The vertical intake is protected by stationary screens. Thermal effluent water ($\Delta T = 19^\circ\text{F}$) is discharged through six discharge pipes, which converge into a common submerged discharge slot of 15 ft by 80 ft just upstream of Keowee Dam.

Plant Site Characteristics

The Oconee Nuclear Station is located on Lake Keowee, South Carolina, a freshwater impounded reservoir in the Savannah River System. Lake Keowee, covering 18,500 acres, is a thermally stratified lake (May through November). The power station utilizes hypolimnetic withdrawals from the lake for cooling. Lake Keowee was impounded only recently, and population dynamics of the aquatic communities may not have attained equilibrium because of morphological changes (i.e., increased bottom area), increased nutrient supply, and other natural successional characteristics of aquatic ecosystems.

Operating History

As of January 1976, Oconee Nuclear Station Units 1, 2, and 3 had been in commercial operation for 2.5, 1.75, and 1 years respectively (Table 1.2).

Preliminary Assessment

Hydrothermal monitoring. Oconee is located on Lake Keowee, an irregularly shaped reservoir. The complex geometry of this site is a significant obstacle to the general applicability of the data. The plant has a submerged slot discharge.

The monitoring program has a number of problems (Table 1.3). The boat surveys seem inadequate. The elapsed time from the first measurement to the last measurement is often 8 hr, so what is measured should not be thought of as a plume in any conventional sense. Moreover, the data presentation lacks detail, and the hydrothermal study has no velocity data. In summary, Oconee is not a good choice for detailed hydrothermal analysis.

Ecological evaluation. Ecological evaluations were made on the thermal effects of the plant on phytoplankton, periphyton, zooplankton, benthos, and fish and on the impingement and entrainment effects of the plant.

1. Thermal effects. Whole water samples of phytoplankton were collected monthly in the euphotic zone and at lower sampling depths. Monthly data are presented as numbers of cells per milliliter, biovolume (times $10^4 \mu\text{m}^3/\text{ml}$), and chlorophyll α (active and total) concentrations at the two sample depths for the dominant phytoplankton taxa (Table 1.5). Duplicate artificial substrates were submerged to 5 ft at two control stations and at one discharge station in Lake Keowee. Periphyton production data are presented as milligrams of organic matter per square meter per day for each station. Periphytic diatoms species are also listed by percent composition at each station. Duplicate samples were collected monthly at the surface, mid-depth, and near bottom with a Schindler-Patalas plankton trap. Data for all zooplankton taxa are given monthly as standing crops (numbers per liter) at various depths at each station. Benthic macroinvertebrates were sampled from Lake Keowee and Hartwell four times per year with a modified Petersen dredge at ten stations. Nonquantitative littoral sampling with a sweep net was performed along the shore nearest each station. Survey of the invertebrate taxa are presented as numbers of individuals and biomass at each station. Data necessary to characterize the fish population dynamics of Lake Keowee have been collected using seines, frame trawls, gill nets, electrofishing gear, and rotenone. Life history studies of four indicator fish species at both discharge and control areas include studies on age, growth, reproduction, and food habits.
2. Impingement. Monitoring of the intake screens was performed by biweekly visual observations and when the screens were periodically removed for cleaning. Data are presented as total number and weight of species impinged, species composition (percent), percent of fish in each of five size groups, and state of decomposition. Pertinent data also include weekly water temperatures, dissolved oxygen, and total time pumps were operating two weeks prior to screen inspection.
3. Entrainment. Zooplankton entrainment was determined six times per year from samples collected at the precondenser and discharge stations. Phytoplankton entrainment was determined six times per year, and differences in the standing crops (biovolume), chlorophyll α , phaeopigments, and carbon assimilation rates (milligrams of carbon per cubic meter per hour) at the intake and discharge were reported. Mechanical and thermal effects are discussed.

Chemical effluents. Chlorine and other biocides were not used in the plant condensers. The following parameters were monitored quarterly: mercury, zinc, nickel, copper, chromium, aluminum, and cadmium. Parameters monitored monthly included: manganese, iron, silicon, NO_3 turbidity, (Jackson turbidity units), and total phosphates.

Avian mortality. Avian mortality was considered for the impact of both cooling towers and transmission lines.

1. Cooling towers. Condenser waste heat is dissipated by once-through cooling.
2. Transmission lines. The applicant is constructing a total of 390 miles of transmission lines with approximately five towers per mile. No monitoring data on bird populations are given in Technical Specifications.

Salt drift. Condenser waste heat is dissipated by once-through cooling.

Herbicides. No mention of herbicide use is made by the applicant with respect to maintenance of vegetation in transmission rights-of-way.

D. SAN ONOFRE

Plant Design and Characteristics

Unit 1 of the San Onofre Nuclear Generating Station consists of a PWR with a 430-MW(e) generating capacity. Waste heat is dissipated by once-through cooling of the condenser (Table 1.1). Cooling water is withdrawn from the Pacific Ocean through a single vertical intake port located 3200 ft offshore at a depth of 27 ft. The intake port is fitted with a velocity cap to reduce numbers of small fish entrained in the cooling system. The cooling water is passed through an intake conduit to an onshore screenwell consisting of a coarse bar screen and finer traveling screens. Thermal effluent water ($\Delta T = 19^\circ F$) flows through a 12-ft-diam, 2600-ft-long conduit to a single vertical port. The port has an average diameter of 20 ft and is located in 12 ft of water.

Plant Site Characteristics

The San Onofre Nuclear Generating Station (SONGS) is located on the Pacific Ocean approximately half the distance between Los Angeles and San Diego. The site occupies a stretch of coastline 0.75 miles long and 0.17 miles wide and bounded by the Pacific Ocean. Water movement near the site is the result of wind drift, wave action, and tidal, coastal, and residual currents. The most significant near-shore effect is due to tidal currents, which are a combination of back and forth oscillations and clockwise rotations.

Operating History

As of January 1976, San Onofre 1 had been in commercial operation for eight years. This is the longest operating history of any candidate plant (Table 1.2).

Preliminary Assessment

Hydrothermal monitoring. The oceanic environment of San Onofre is unique among the candidate plants, but it is of considerable importance in view of the offshore power plant concept.

The San Onofre Environmental Technical Specifications program is relatively new, and only one report had been issued at the time of the preliminary screening. The staff also examined summary reports prepared by the utility that are based on data going back to 1963. The present monitoring program is of good quality (Table 1.3). The use of infrared temperature scanning yields a nearly instantaneous picture of the plume. The presentation and analysis of the data is also very good. The main drawback to this monitoring program is the infrequency of the surveys.

Ecological evaluation. Ecological evaluations were made on the thermal effects of the plant on phytoplankton, zooplankton, benthos, and fish and on the impingement and entrainment effects of the plant.

1. Thermal effects. Phytoplankton sampling was conducted concurrently with zooplankton sampling at both 1-m and 8-m depths. Data are reported as milligrams per cubic meter for chlorophyll *a* and phaeopigments and as relative abundance of each plankton species (Table 1.5). Bimonthly samples were collected at two discharge and five control stations, with the stations being spaced at increased distances upcoast and downcoast from the discharge area. Samples were taken at two discrete strata (0 to 5 m and 5 to 10 m) using a plankton pump system. All stations were located along the 10-m depth contour to permit correlation of plankton data with physical and biological data collected during related studies. Data are presented as numbers per cubic meter and percent of total number of both sample strata for all zooplankton taxa at all stations. Twelve benthic stations (four discharge areas, six control areas, and three kelp beds) were sampled. Diver-biologists identified and enumerated all dominant organisms observed within each square meter of the 1- by 10-m band transects. Estimates were made of the percent areal coverage of colonial and encrusting species. Thus, data are presented as total abundance and frequency of occurrence of each invertebrate taxa. To support the benthic survey, replicate settling plates were installed at two diving stations in a discharge and control area. Each settling rack contained ten plates arranged horizontally, and replicate plates from each station were removed sequentially at 3-, 6-, 9-, and 12-month intervals. The first set was removed in August 1975, and data were presented as number of individuals per species, diversity indices, and biomass. Aerial infrared color photographs of three kelp beds were taken quarterly to monitor qualitative changes in extent and configuration of the kelp canopy. Five intertidal stations, including one control and four discharge stations, were established along a 2-m-wide transect perpendicular to the shore, which traverses several ecological zones. Quantitative assessments were made quarterly at

three fixed 0.25-m² quadrats at each station. Data are given as species composition of all macrophytes and macrofauna. Nekton surveys were conducted on a quarterly basis. During each survey, two replicate gill nets were set at each of six stations, three in control zones and three in discharge zones. Within each zone, nets were placed at the bottom and near the surface. Data are presented as species composition, sex composition, numerical abundance, size ranges, and frequency of occurrence of resident and transitory species. Distribution of fishes is also related to offshore ecological communities and bottom types.

2. Impingement. Impingement was monitored weekly during normal station operation and four other times during periods of heat treatment. Data are presented as total number and weight, size (standard lengths), and sex of each species.
3. Entrainment. A detailed description of the plankton entrainment program was presented in the 1976 Semiannual Operating Report and could not be reviewed for this preliminary screening.

Chemical effluents. Heavy metals were monitored quarterly at SONGS in both the receiving water (by Van Doren bottles) and in the bottom sediments (by grab samples). Collected samples were analyzed for copper, chromium, nickel, and iron. Copper, nickel, and chromium were expected to be the most significant contaminants at discharge concentrations of 1.6 ppb, 0.2 ppb, and 2.0 ppb respectively.

Chlorine was monitored biweekly at discharge and control stations, and concentrations averaged 0.1 ppm at the discharge. Chlorine was used infrequently because heat treatment was the primary method used to control growth of fouling organisms.

Avian mortality. Avian mortality was considered for the impact of both cooling towers and transmission lines.

1. Cooling towers. Condenser waste heat is discharged directly into the Pacific Ocean.
2. Transmission lines. A distance of 1437 ft of additional transmissions lines were needed to connect SONGS with the applicant's transmission system. No monitoring data on bird populations are required by the Technical Specifications.

Salt drift. Condenser waste water is discharged directly into the Pacific Ocean.

Herbicides. No mention is made of herbicide use by the applicant for vegetation management of transmission rights-of-way. The only new transmission line construction required for Unit 1 is a distance of 1437 ft.

E. PALISADES

Plant Design and Characteristics

The Palisades Plant uses a PWR to produce 700 MW(e) (Table 1.1). Before 1975, the plant used once-through cooling; however, a change to closed-cycle cooling using mechanical draft towers was undertaken. The water for the once-through system was withdrawn from Lake Michigan through an intake crib located in 20 ft of water. The water passed through an 11-ft-diam pipe to an onshore intake structure protected by trash racks and traveling screens. The effluent was heated 28°F and discharged through a shoreline surface canal.

Plant Site Characteristics

The Palisades Nuclear Generating Plant is located on the eastern shore of Lake Michigan (southern basin) in Van Buren County, Michigan. The site was a former quarry and is surrounded by sand dunes on three sides. Lake Michigan is dimictic (two overturns per year), with overturns occurring in late fall and early spring. During winter, the lake is isothermal, and the lake is stratified during summer.

Operating History

Palisades operated in the once-through cooling mode for about 1.5 years (January 1972 to August 1973). The plant was shut down from August 1973 until April 1975. Since April 1975, the plant has operated with cooling towers. Additional details are given in Table 1.2. Because of the discontinuous operation of this facility, Palisades was judged unsuitable for our analysis.

Preliminary Assessment

Hydrothermal monitoring. In several respects, Palisades can be considered prototypical of a class of nuclear power plants. It is located on a straight stretch of Lake Michigan shoreline and uses a simple surface canal to discharge its heated effluent. However, this desirable quality is offset by its poor operating record. Furthermore, Palisades has changed from once-through cooling to cooling tower operation.

The Palisades Technical Specification monitoring program is not unusual (see Table 1.3). Temperature surveys have been made using boat-mounted thermal sensors to measure both horizontal and vertical temperatures. No discussion of instrumentation or elapsed time was found. Surface isotherm maps and some vertical profiles derived from these measurements were presented. A single airborne infrared thermal map was also reported. No velocity data were taken in the regular monitoring program. There is interesting data on thermal transients during startup and shutdown, sinking plumes, and the effect of the plume on near-shore ice formation. A significant body of thermal and velocity data were obtained by Argonne National Laboratory^{1,2} using their own boat-mounted sensors.

Ecological evaluation. Ecological evaluations were made on the thermal effects of the plant on phytoplankton, zooplankton, benthos, and fish and on the impingement and entrainment effects of the plant.

1. Thermal effects. At each discharge and control station, 80 liters of water were pumped from 5 ft, 10 ft, and 15 ft depths, respectively, through a plankton net. Data are presented as packed cell volumes (milliliters) and number of cells per liter for each major genera (Table 1.5). Zooplankton were collected in the same manner as phytoplankton. Data are expressed as numbers of organisms per liter for dominant genera. Three replicate samples were taken at each discharge and control station quarterly with a 0.5-ft² ponar grab. Data are presented by station as the average number of organisms per square foot for major groups. Sediment types and water depth are also described for each sample locality. Sampling stations for fish were established by a fan-shaped sampling grid, which was composed of nine lines radiating from the plant and four concentric semicircles with radii of 0.5, 1, 2, and 5 miles. The inner radii (0.5 and 1 mile) represent the discharge stations and the outer radii (2 and 5 miles) are controls. Monthly nekton sampling was conducted with gill nets, seines, and trawls in both discharge and control stations. Gill nets were fished at various depths, and shoreline seining was performed during the day and night. Population estimates of carp and alewives in discharge areas have been made based on mark-and-recapture methods.
2. Impingement. The total number, total weight, and size range for all species impinged on the screens are reported weekly. Daily temperatures are given, but the number of pumps operating is omitted.
3. Entrainment. The mortality of zooplankton (rotifers, copepods, and cladocerans) was assessed by the difference in the percent dead at the intake and discharge and also by the vital staining techniques. Phytoplankton entrainment was determined by differences in the primary productivity rates (¹⁴C) at the intake and discharge.

Chemical effluents. Chlorine measurements at the point of discharge and throughout the area of chlorine dissipation were measured. Residual chlorine values were predicted to be 0.022 ppm after discharge. Turbidity was not expected to increase appreciably during plant operation.

Avian mortality. Avian mortality was considered for the impact of both cooling towers and transmission lines.

1. Cooling towers. Waste condenser water was dissipated through the use of mechanical-draft cooling towers. No monitoring on bird populations are required by the Technical Specifications.
2. Transmission lines. Palisades must build 40 miles of new transmission lines to carry power to various substations. No predicted impact on bird populations is made in the FES, although the bald eagle (an endangered species) is reported in the site area at various times of the year. No monitoring data are required by the Technical Specifications.

Salt drift. Cooling towers 50 ft high are surrounded by sand dunes over 100 ft high, and many trees at the site are 50 to 80 ft tall. By placing the towers in the dune valleys, the effects of vapor plume and drift from the cooling towers may be attenuated locally. Effects on plant communities are predicted to be minimal except in close proximity to the power station site. No monitoring data are required by the Technical Specifications.

Herbicides. No mention is made of the use of herbicides by the applicant for vegetative management of transmission rights-of-way. A 40-mile 345-kV line will be built, resulting in the clearing of 2250 acres.

F. GINNA

Plant Design and Characteristics

The Ginna Power Station consists of a PWR system designed to produce 496 MW(e) power (Table 1.1). Lake Ontario is the source of the cooling water, which is withdrawn through the ports of the octagonal intake structure lying 33 ft below the mean lake level. Intake ports are fitted with debris screens. Water is conducted shoreward through an intake tunnel (10-ft diam) that is 3100 ft long. After passage through the tunnel, water is passed through coarse trash screens and a fine mesh traveling screen. Waste heat is dissipated by once-through cooling of the condenser ($\Delta T = 18.4^{\circ}\text{F}$), and effluent water is discharged into a surface canal that opens into Lake Ontario at the shoreline. Fish are discouraged from entering the canal by an electric fish screen.

Plant Site Characteristics

The Ginna Plant is located on the south shore of Lake Ontario approximately 20 miles from Rochester, New York. Lake Ontario is a dimictic lake considered to be isothermal (32°F) in winter, followed by a period of spring turnover. The lake attains a vertically stratified regime in the summer. Wind-driven currents are the most prominent dynamic feature of the lake.

Operating History

As of January 1976, Ginna had been in commercial service for nearly six years. This constitutes the second largest operating history among the candidate plants (Table 1.2).

Preliminary Assessment

Hydrothermal monitoring. Like Palisades, Ginna is prototypical of lake-shore plants using surface discharges. The geometric parameters are somewhat more complex at Ginna because the discharge canal has a trapezoidal cross section and the adjacent Smoky Point Peninsula tends to shield the plant from ambient currents.

The data collected for the Technical Specifications are not significant, but much other information is available. Table 1.3 refers to a program of monthly plume surveys required by the New York State Department of Environmental Conservation. In this program, more than 35 plumes have been surveyed at four depths using boat-mounted thermistors. Although neither tabular data nor discussions of the instrumentation are available, the horizontal isotherm plots presented are readily usable. Data are not available for the mid-winter months or for velocities. Another body of usable data consisting of more than 70 surface isotherm maps in all months has been obtained by Lake Ontario Environmental Laboratory^{3,7} using airborne infrared imagery.

Ecological evaluation. No data are available on the thermal effects of Ginna on phytoplankton, zooplankton, benthos, and fish (Table 1.5). Also, no data are available on the effect of Ginna on entrainment. Two special studies on impingement that are not required by Technical Specifications are available. The first deals with the number and species impinged, survival rates, effects of environmental conditions on impingement rates, determination of impacts associated with population parameters, and the impacts of impingement on various species. The second study concerns the effect of changes in plant flow rates on the level of impingement.

Chemical effluents. To date, no chemical effluent data have been presented from Ginna. Sodium sulfate was the chemical released in the largest quantity (100,000 lb/year), and chlorine values were expected to be 0.04 ppm in the discharge waters.

Avian mortality. Avian mortality was considered for the impact of both cooling towers and transmission lines.

1. Cooling towers. Condenser waste heat is removed by once-through cooling; therefore, cooling tower problems are not applicable to this reactor.
2. Transmission lines. Only about 3.5 miles of new transmission lines are needed for this power station (0.6 miles of additional lines are buried). No prediction of impact on bird populations is made, although the FES states that the Ginna site is located along important bird migration corridors of the Eastern Flyway. The migration path is used by an estimated 175,000 to 400,000 ducks and 75,000 to 150,000 Canada geese each year. No monitoring data are required by the Technical Specifications.

Salt drift. The condenser waste heat is removed by once-through cooling.

Herbicides. The transmission-line corridor is maintained by mechanical clearing, and the applicant reports that no herbicides are used.

G. VERMONT YANKEE

Plant Design and Characteristics

The Vermont Yankee Power Station uses a boiling-water reactor (BWR) that produces 514 MW(e) power (Table 1.1). The intake is a reinforced concrete structure on the river bank fitted with trash racks and traveling screens. Waste heat is dissipated through a hybrid system. When ambient river temperature is 70°F or greater, all waste cooling water is diverted to the mechanical-draft cooling towers. When ambient river temperature is less than 70°F, waste cooling water may be discharged directly by once-through cooling or part of the effluent may be diverted to the towers for cooling and for subsequent mixing with once-through heated effluent to lower the total effluent temperature before discharge.

The hybrid system is used to restrict the ΔT to 5°F and to limit the rate of change in river temperature to 0.5°F to 1.0°F per hour at different seasons of the year. The surface canal discharge structure on the river bank is fitted with 27 concrete deflector blocks to aerate discharge water.

Plant Site Characteristics

The Vermont Yankee Power Plant is located on a freshwater impounded area of the Connecticut River known as Vernon Pond, which was created in 1909 by construction of the Vernon Dam, in southeast Vermont. The water impounded covers an area of approximately 2500 acres and varies in depth from 15 to 50 ft.

Operating History

Vermont Yankee operated strictly as a closed-cycle cooling-tower plant for about one year until February 1974. Since that time, the pattern of operation has been irregular, depending on the river conditions. For example, the plant used once-through cooling in April, hybrid cooling in May, and cooling towers in June 1975. The total operating history of the plant as of January 1976 was three years. Additional details are presented in Table 1.2.

Preliminary Assessment

Hydrothermal monitoring. Vermont Yankee is designed to operate either as a once-through plant or a cooling tower plant. Until February 1974, it operated strictly as a cooling tower plant. From February through April 1974, tests were conducted to see what effect once-through or hybrid operation would have on the Connecticut River. Since that time, the mode of operation has been variable. Thus, Vermont Yankee has little operational experience as a once-through plant.

Because Vermont Yankee had a very small thermal plume when operated with cooling towers, its monitoring program was very modest. As Table 1.3 shows, this merely consisted of hourly upstream and downstream temperature recordings. During the February through April 1974 test period, an intensive monitoring program was executed.⁸ This included 69 three-level thermal surveys using boat-mounted thermistors and fixed velocity measurements. The data were presented using horizontal isotherm maps for the three layers, three vertical cross-section thermal plots, and vertical temperature profiles at 26 stations. The analysis of the data was very good. This was an excellent study, but its short duration limited its usefulness for the environmental Technical Specifications review program.

Ecological evaluation. Ecological evaluations were made on the thermal effects of the plant on phytoplankton, zooplankton, benthos, and fish and on the impingement and entrainment effects of the plant.

1. Thermal effects. From March through December, samples were collected utilizing the same methods and at the same stations as the zooplankton. Data are given as mean annual percentages of diatoms, flagellates, greens, and blue greens at each station for 1970 through 1974 (Table 1.5). Zooplankton were collected by vertical hauls with

a #20-mesh plankton net and through plankton pumps sampled concurrently with water quality monitoring. Samples were collected monthly at two stations above, two stations below, and two stations adjacent to the plant. Data are presented as mean annual percentages of Rotatoria, number of organisms per liter, and number of genera. Benthic macroinvertebrates were collected from March through December at three stations above and four stations below the plant with modified Henson traps and a 9-in. Ekman dredge. Ekman-dredge collections consisted of a minimum of 9 hauls per station and averaged 12 hauls per station. Monthly data are presented as number of species and individuals per station, species diversity, and predominant forms. Nekton were sampled with trap nets, seine hauls, gill nets, and minnow traps at several stations in the Connecticut River above and below the plant. Data are presented as total numbers and total weight for each species captured during each year. In addition, food habits were studied for resident river species.

2. Impingement. The plant operates in the closed-cycle or hybrid mode most of the time, so there is little impingement.
3. Entrainment. Entrainment mortality for zooplankton was determined at approximately two-week intervals during the closed-, hybrid-, and open-cycle modes. On each sampling date, samples were taken at the condenser intake and either at the discharge before entering the cooling towers or after passage of water through the towers (blowdown). Effects of plant passage on phytoplankton were determined by differences of chlorophyll *a* at the intake and discharge.

Chemical effluents. Monthly sampling of turbidity (Jackson Candle Units) and pH were made at the Vermont Yankee Station, and minimum and maximum monthly values are reported.

Avian mortality. Avian mortality was considered for the impact of both cooling towers and transmission lines.

1. Cooling towers. Vermont Yankee uses a hybrid cooling system combining both once-through cooling and cooling towers, depending on ambient water temperature. No monitoring data on bird populations are required by the Technical Specifications.
2. Transmission lines. The applicant proposes the addition of 51 miles of new transmission lines for distribution of power to other substations. Two 345-kV lines span Vernon Pond. Although waterfowl are present in the area, apparently they are not abundant. No monitoring data on bird populations are required by the Technical Specifications.

Salt drift. Condenser waste water is cooled by a hybrid system, a combination of once-through cooling and mechanical-draft towers, to ensure that effluent water will not exceed 5°F above ambient river temperature. No monitoring data were required by the Technical Specifications concerning salt drift.

Herbicides. The Vermont Yankee program for maintenance of transmission lines uses herbicides, but it also includes erosion control and selective cutting. When herbicides are used to control growth in the rights-of-way, the applications are made shortly after clearing and every two or three years thereafter. No monitoring data are required by the Technical Specifications concerning herbicide use.

H. ARKANSAS

Plant Design and Characteristics

The Arkansas Nuclear One Station consists of two PWRs (Unit 1 and 2) producing 820 MW(e) and 902 MW(e) respectively. The condensers of Unit 1 are cooled by once-through cooling water, and Unit 2 (when completed) will use a closed-cycle system with a natural-draft cooling tower (Table 1.1). Water for cooling will be taken directly from the Illinois Bayou arm of Lake Dardanelle and then passed through a 4400-ft-long canal (85 ft wide and 12 ft deep) to the station's intake. The intake pumps for Unit 1 are protected by bar racks and traveling screens. Waste water ($\Delta T = 15^\circ\text{F}$) is discharged into a 520-ft-long discharge canal and then into Lake Dardanelle.

Plant Site Characteristics

Arkansas Nuclear One is situated on a peninsula on the northern bank of Lake Dardanelle in Pope County, Arkansas. Lake Dardanelle, a man-made lake, is 51 miles long, with a maximum depth of over 60 ft and a surface area of 36,600 acres. The fluctuations in water level are mediated by upstream and downstream dams. The lake is relatively young (eight years), and the structural and functional processes related to the ecological communities have probably not attained dynamic equilibrium.

Operating History

As of January 1976, Arkansas Unit 1 had a commercial operating experience of about one year. Unit 2 had not yet begun operation. More details can be found in Table 1.2.

Preliminary Assessment

Hydrothermal monitoring. As reflected in Table 1.3, there were no hydrothermal monitoring data available for Arkansas in December 1975.

Ecological evaluation. No data are available on the thermal effects of Arkansas Unit 1 on phytoplankton, zooplankton, benthos, and fish (Table 1.5). Also, no data are available on the effect of Arkansas Unit 1 on entrainment. Extensive impingement monitoring has been performed since June 1974 because of the magnitude of the threadfin shad impingement problem in Lake Dardanelle. The basic impingement monitoring program includes one 8-hr sample every day extrapolated to 24-hr values. Six weeks per year, samples are taken every 8 hr during a 24-hr period for six days per week. Data are reported as total number and weight of each species impinged per 24 hr, and maximum and modal lengths of each species. Supporting data given include ambient water temperatures, air curtain status (on or off), and the number of circulating pumps operating.

Chemical effluents. Thus far, only nonroutine reports have been presented for the Arkansas project. Sodium sulfate at 4 ppm and chlorine at 0.5 ppm concentration in the discharge were predicted to be the most significant effluent problems.

Avian mortality. Avian mortality was considered for the impact of both cooling towers and transmission lines.

1. Cooling towers. Waste condenser heat is dissipated by a once-through cooling system. (Cooling towers are planned in the future for Unit 2.)
2. Transmission lines. The applicant plans to add 167.6 miles of new transmission lines to the system. No predicted impact on bird populations is made; however, the site is particularly rich in waterfowl populations. Although no numbers are given, wintering and early spring populations of both bald and golden eagles are reported. The Technical Specifications do not require monitoring of changes in bird population due to transmission lines.

Salt drift. A once-through cooling method is employed at Arkansas Unit 1.

Herbicides. The applicant must clear 3700 acres of rights-of-way for the five transmission corridors. However, herbicides will not be used because selective maintenance will be practiced.

III. RECOMMENDATIONS FOR SAMPLING POLICIES

A. GENERAL CONSIDERATIONS IN SAMPLING POLICY

The sampling policy should be designed so that area differences are compared, instead of individual station or point differences. In order to delineate the true discharge and control areas, an intensive hydrothermal monitoring program should be established so that accurate probability temperature density functions can be mapped. Once this has been accomplished, each of the areas designated as control and discharge should be divided into appropriate quadrats or subplots, and the appropriate number of samples at each sampling period should be taken from each of these subplots. Examples of the appropriate number of samples to be taken and the distribution of sampling periods will be discussed in the following section. Quadrats within each area (control or discharge) should be established according to their similar physical and chemical characteristics. For example, some of the physical parameters that should be considered are water depth, bottom type, current patterns, and turbidity. Some chemical factors that should be considered are pH, dissolved oxygen, salinity, and nutrients (NO_3 , PO_4 , etc.). If the quadrats to be sampled in the control area include shallow sandy areas and also deep muddy channels, then these two distinct areas should be considered separately and compared to similar type areas receiving thermal effluents.

The concept of sampling on a large area basis as opposed to sampling various fixed stations scattered throughout the aquatic system is a more realistic biological sampling policy. This approach allows for a better evaluation of the effect that the power plant is having on the total aquatic system. Due to the complexity and interaction of the spatial and temporal distribution patterns of the organisms in the aquatic environment with the physical and chemical complexities of the system, meaningful analysis and evaluation of potential plant impacts based on fixed biological station measurements cannot be made. However, hydrothermal monitoring is best sampled by a fixed thermograph network. The ultimate goal in impact analysis and assessment is to evaluate the effects of power plant operations on the structural and functional dynamics of biological populations in an aquatic ecosystem. Therefore, monitoring programs should be designed for this purpose.

B. GENERAL CONSIDERATIONS IN THE DESIGN OF ECOLOGICAL MONITORING PROGRAMS

In this section, recommendations for potential sampling policies and monitoring programs will be discussed. A good monitoring program should also include an ecosystem level model so that the behavior of the ecosystem under study can be predicted over different operating modes of a plant. This approach also helps in the determination of the important ecological parameters that should be monitored and helps to develop an understanding of the ecological processes in the system under study. For example, consider a simple ecological system consisting of four main compartments (trophic

levels) and the various transfer or flow rates between compartments. With a good monitoring program that supplies the proper data for the model, the various transfer functions between the compartments can be determined. The system can then be investigated under different types of perturbations caused by power plant operation without having to initiate more costly and time-consuming monitoring programs.

In designing a monitoring program, one must keep in mind that the system being sampled is not static but dynamic in nature, with complex inter- and intra-compartmental relationships. The rate of sampling can be determined as follows. Assume that the compartment with the shortest turnover time is (f_{min}). By Nyquist⁹ sampling theorem, the sampling rate must be at least $f = 1/2(f_{min})$. While a sampling rate of at least f is necessary, several authors have suggested a faster sampling rate. In constructing ecosystem models, it might be necessary to estimate the turnover rate accurately. However, if this is too expensive, one can compromise without too much concern because the primary purpose of a monitoring program is to determine the long-term trends in an ecosystem. The rate of sampling, then, is determined by the compartment or trophic level that exhibits the shortest turnover rate. This then establishes the minimum time frame of interest. In this section, a step-by-step procedure outlining the various stages of a monitoring program is discussed. This is a general outline and must be modified for a particular site or problem.

1. Monitoring program design

In designing a monitoring program, the following procedure might be useful:

- (a) List the parameters ($P_1, P_2 \dots P_x$) to be investigated. Discuss the reasons for desiring to monitor the parameters and how the plant operation might affect the parameter(s).
- (b) If possible, construct an energy flow or food web diagram of the aquatic system under investigation.
- (c) Determine from the literature:
 - (1) the turnover rates of each parameter;
 - (2) the average coefficient of variation (CV) of each parameter during the shortest of the turnover periods f_{min} , where $f_{min} = \min (f_1, f_2 \dots f_p)$;
 - (3) if possible, obtain the (CV) during a period of length $1/2(f_{min})$ (see text for explanation).
- (d) Define the stressed and control areas and describe them as accurately as possible. If the stressed area is not

homogeneous and has several natural strata, list those and the proportion of the area each covers. It is preferable to have the control and discharge areas similar in their chemical and physical characteristics.

- (e) Obtain an initial estimate of the sampling plan based on prior knowledge of the coefficient of variation (CV).
- (f) If feasible, obtain field estimates of the CV using the sampling plan designed in step (e). The period of pilot study must be of length f_{min} or less. In this initial sampling period, monitoring at a rate faster than that suggested by the sampling plan of step (e) might be worthwhile, along with sampling at several locations within the control and stressed areas. Because this initial monitoring program will be of short duration (2 to 4 weeks), this is feasible. The pilot study must be conducted when the biological parameters being measured are abundant.
- (g) Use the results of step (f) to decide:
 - (1) number of samples required during period f_{min} ;
 - (2) number of stations to be sampled in each area of interest.
- (h) Monitor the aquatic system with this sampling plan for a reasonable length of time prior to the operation of the plant.
- (i) Update the monitoring program before the plant goes into operation.
- (j) Analyze the data before the plant goes into operation, and construct whatever models are deemed necessary.
- (k) Monitor the system during plant operation. Record pertinent additional information such as discharge flow rate, discharge temperature, and plume surveys, etc.
- (l) At the end of a prespecified period, analyze the data for the operational period.
- (m) If a model has been constructed to describe the system, check to see if the observed values are within the confidence band of the predicted values. If a change of X percent is observed, use the models to predict what long-range effect this change could have on the system.

- (n) Re-evaluate all models.
- (o) Based on the outcome and decisions of the preceeding steps, determine whether to discontinue monitoring, scale down the monitoring program, increase the intensity of monitoring, or modify plant operation.
- (p) At all steps of monitoring, data must be recorded and reported in proper machine-readable form for data-base development and analysis.

2. Methodology for sample size calculations

The sample size can be determined based on several different types of policies. It may be necessary to keep the sampling plan and the methodology simple so that field personnel can do these calculations rapidly and without a great deal of training.

Suppose the CV of parameter P_1 (phytoplankton, for example) is known. Furthermore, assume that the turnover period of parameter P_1 is two weeks. One must now specify two constants:

- (1) the half-length of the confidence interval ($= d$) (this is usually expressed as a percent of the unknown true mean), and
- (2) the type I error, α .

Given d and α , the sample size n is given by:

$$n = \left[\frac{t_{\nu, \left(\frac{\alpha}{2}\right)} (CV)}{d} \right]^2$$

where

- $\nu = n-1 = \text{degrees of freedom,}$
- $CV = \text{coefficient of variation,}$
- $t_{\nu, \left(\frac{\alpha}{2}\right)} = \text{the } t \text{ variate obtained from tables of student's } t \text{ distribution, with } \nu \text{ degrees of freedom, and}$
- $d = \text{half-length of the confidence interval.}$

For example, let $CV = 9\%$, $d = 5\%$, and $\alpha = 0.05$. Since t_{ν} is a function of n , n is obtained iteratively. Assuming n to be ∞ , we obtain $t_{0.025} = 1.96$; then $n' = \left(\frac{1.96 \times 9}{5} \right)^2 = 13$.

The appropriate value of n greater than n' can be found by trial and error using the relation given above and a table of Student's t distribution. For the example above, n was obtained to be 15.

Consider the case of chlorophyll *a* data at Peach Bottom during September 1975 (Vol. 3, Sect. IV.B.1.a). Based on previous analysis, Stations 601, 604, 605, and 607 were shown to be relatively homogeneous. Assume for the present that the data collected over a 14-day period in September between 1972 and 1975 are results from a pilot study.

In Table 1.6, a simple one-way analysis of variance is summarized for these data. The day of sampling is the treatment and the estimate of the CV is 9%. When the CV is 9%, the derived half-length of the confidence interval has been determined to be 5% of the true mean; and when $\alpha = 0.05$, the number of replicates required is 15.

Table 1.6. Analysis of variance for chlorophyll *a* data^a collected during a 14-day period

Source	df ^b	ss ^c	ms ^d
Day	6	0.67	0.112
Residual	23	0.34	0.015
Corrected total	29	1.02	

^a Response is $\log_{10}$ (chlorophyll *a* + 1).

^b df = degrees of freedom.

^c ss = sum of squares.

^d ms = mean square.

The next question to be answered is how often one should sample during this 14-day period. From Table 1.6, an estimate is obtained of σ_D^2 , the variance component due to date (day) to be 0.024. If n is the number of days to be sampled, then the variance of $\bar{X}$ where $\bar{X} = \frac{(\bar{X}_1 + \bar{X}_2 \dots \bar{X}_n)}{n}$ is

$$V(\bar{X}) = \frac{1}{nk} (\sigma^2) + \frac{1}{n} (\sigma_D^2) ,$$

where k is the number of replicates per sampling day. Constant variance over sampling days has been assumed. Since $nk = 15$ by our previous calculation,

$$V(\bar{X}) = \frac{\sigma^2}{15} + \frac{\sigma_D^2}{n} ,$$

$$\text{and } \sigma^2 = 0.0151 \text{ and } \sigma_D^2 = 0.024 .$$

$$V(\bar{X}) = \frac{0.0151}{15} + \frac{0.024}{n} = 0.001 + \frac{0.024}{n} .$$

Clearly, this variance is minimized if n is infinite. However, because there are only 14 days in the period of interest, sampling can occur once a day. This does not seem to be feasible. One must obtain a

compromise between the number of days sampled during the 14-day period and the number of replicates per day. One possible method to determine the number of days to be sampled is based on costs.

Let C_1 be the cost of sampling on a given day (e.g., the cost of initiating a boat trip or the cost of manpower) and let C_2 be the cost of each sample. To obtain a sampling policy that reduces the variance of the mean $\bar{X}$, given the cost functions, the Lagrangian function ∂ is minimized by:

$$\partial = \frac{\sigma^2}{nk} + \frac{\sigma_D^2}{n} + \lambda^2(nC_1 + nk C_2 - C) ,$$

where

λ^2 = Lagrangian constant

$C = nC_1 + nk_2$ = total cost.

An optimal value for n and k can be obtained using standard techniques.

In designing a monitoring program, solving for n and k is not important: rather, importance lies in solving for n given nk . Given $nk = N$, the number of days to be sampled (n) is given by:

$$n = \left(\sqrt{\frac{\sigma_D^2}{\sigma^2}} \sqrt{\frac{C_2}{C_1}} \right) (N) .$$

For example, if $N = 15$ (as determined in the last section), $\sigma^2 = 0.0151$, $\sigma_D^2 = 0.024$, and if the cost function can be reduced by the simple relationship, $C_2 = 2^2 C_1$, then $n = 73.5$.

For various feasible values of ξ (defined to be those values for ξ for which $n < 15$), the corresponding values of n and k are given in Table 1.7. As expected, if the cost of initiating a sampling trip decreases, then sampling on more days is preferable. Conversely, if the cost of initiating a field trip is prohibitive, then one must sample extensively on any given day.

Table 1.7. Cost functions (L) for various combinations of number of sampling days (n) and number of replicates per day (k)

L	n	k	nk
0.01	1	15	15
0.05	4	4	16
0.10	8	2	16
0.15	11.0	2	22
0.20	15.0	1	15

The cost function discussed above is not realistic; however, it illustrates how one may design monitoring programs using some simple techniques. Furthermore, the method outlined above is a good first approximation to the sampling rate problem, given that the turnover rate of the ecological parameter under investigation is known.

3. Conclusions

In this section, a simple but effective protocol for monitoring was discussed. An attempt has been made to keep the methodology simple at the cost of statistical purity. Given the current state-of-the-art, such simple methods are adequate for designing and planning ecologically meaningful monitoring programs.

C. RECOMMENDATIONS FOR TECHNICAL SPECIFICATIONS

The following recommendations are proposed for improving the design of Technical Specifications ecological and thermal monitoring programs; to provide a means for flexibility in Technical Specifications when conditions warrant change; and to provide specific guidelines for implementing standardization of the sampling techniques, statistical analysis, and reporting formats.

1. Hydrothermal monitoring

In planning hydrothermal monitoring programs to be required under non-radiological environmental Technical Specifications, two goals must be kept in mind. The most important of these is that the hydrothermal program must effectively complement the biological monitoring program to ensure that unacceptable environmental impacts do not occur. The second goal is to ensure that specific legal standards are observed.

Biological monitoring alone cannot guarantee that the first goal is met. Without a good picture of the discharge plume, it may not be possible to distinguish natural variations or those caused by other human enterprises from power-plant-induced impacts. Except in catastrophic situations, the ecological impact due to a thermal discharge plume is likely to be a long-term effect. To correctly judge long-term effects, the most useful type of thermal information seems to be probabilistic isotherm maps. Such maps would show, for example, the region within the 5°C excess temperature isotherm 50% of the time. The only suitable way to acquire this information is to establish a network of continuously recording thermographs. Such a network can be the backbone of an environmental Technical Specifications hydrothermal monitoring program. A thermograph network is a sure way of ensuring continuous surveillance to meet legal regulations.

A number of advantages can be gained by supplementing the thermograph data with airborne infrared sensing. In this regard, it is necessary to distinguish between airborne radiation thermometry, which provides water surface temperatures along the line of the flight path, and infrared imaging, which provides a thermal map of a wide area. The latter is obviously more informative, and its information content can be enhanced by computer processing of the image. Infrared imaging provides an unsurpassed means for studying the configuration of the plume at a given instant. This information can be used to check the placement of thermograph monitoring stations and to explain anomalous features in the thermograph data. Infrared imaging is unique in its ability to describe the impingement of the plume on beaches and swampy areas and to show the interaction of the power plant's plume with other sources of heat. Infrared imaging can also help to graphically demonstrate the reasonableness of legal restrictions. This method does have some drawbacks: (1) it can only be done in favorable weather, (2) it requires simultaneous ground truth, and (3) it is relatively expensive. Because infrared imaging senses only the temperature of the upper few microns of water, it tells nothing about the subsurface plume and is of little use during periods of sinking plumes or ice cover. During very calm conditions, imaging can grossly overestimate the extent of the plume. Nevertheless, supplemental airborne infrared imaging could be very useful in most monitoring programs.

There are two techniques in use for making temperature measurements from boats. The moving boat technique consists of a system for periodically or continuously recording temperatures at several depths as the boat moves through the plume region. The boat may follow a predetermined course or preferably may alter its course to "chase the plume," if it is equipped with suitable position-finding instrumentation. Moving-boat data offer good three-dimensional resolution; but, if the plume is large, significant shape changes may occur during a run. Consequently, this method seldom gives a reasonable instantaneous or synoptic map of the plume. There are other drawbacks, including the difficulties in gathering data in rough weather or in shallow areas. The most serious drawback in the context of environmental monitoring is the fact that a continuous data record cannot be obtained for probabilistic analysis. This is a good research method, but it has limited utility in Technical Specifications monitoring programs.

The other boat-oriented method for thermal plume mapping involves stopping the boat at various locations and making vertical temperature profiles. Because of the long time usually required for such surveys, they cannot predict the instantaneous plume and are therefore of limited use. Such data should be collected as a necessary adjunct to the biological sampling program and used only as a check on the primary methods.

With these general comments as background, the following more specific recommendations are offered.

1. Power plants should be instrumented in such a way that all the operating characteristics of hydrothermal interest are fully defined. It is necessary to know on an hourly basis the amount of heat rejected to the water and to the atmosphere by cooling towers, the flow rate and the temperature rise of water withdrawn from and discharged to water bodies. In many plants, the long transit times of water through the plant have caused problems in enforcing temperature rise limitations. Consequently, during the first year of operation, measurements are needed at all possible points of interest, including intake screens, condenser entrance and exit, and discharge structure. This information is best stored on magnetic tape. After a time lag analysis of the first year's data, some of these monitors may well be discontinued. At some plants, salinity measurements may also be needed at these locations.
2. Fixed thermographs recording temperature on an hourly basis are a valuable part of a monitoring program. Data from such networks, available on magnetic tape, can be used to produce probability maps of the plume and can be correlated with meteorological, hydrological, and plant operating data. This appears to be the most useful type of information for ecological impact assessment. At some plants, a parallel system of salinity monitors may be needed.
3. The location of thermographs should be chosen carefully. Particular care should be given to locating the thermograph(s) to be used for control. For operating plants, infrared imaging or moving boat surveys may be useful in this regard. For new plants, preoperational locations can be selected based on model studies, but they should be confirmed using dye injection after the plant has begun to circulate water and before heat rejection begins. If thermographs must be moved, a month of simultaneous data at the new and old stations should be obtained to allow correlation of the locations.
4. The thermograph network is most useful if operation begins early enough that at least one full year of data is obtained before the plant reaches initial criticality. The program should probably be reviewed before commercial operation, 6 months and 12 months after commercial operation begins, and annually thereafter. The program should be continued at least until the plant has achieved a full year of optimum operation. This year should be typical or unfavorable in terms of hydrological and meteorological events, that is, it should not be a year of record-high river flows. At this time, if the plume's behavior is well understood, the plume mapping program could be reduced to a few key thermographs.
5. Consideration must be given to the possibility of sinking plumes occurring due to either the density maximum of water or the salinity differences between the discharge and its surroundings.

6. Current surveys should be performed before and after plant operation. In many cases, these can be relatively short-term studies.
7. Hydrological data such as river flows, flows into and out of reservoirs, and water levels should be reported on magnetic tape.
8. In establishing and reviewing monitoring programs, the personnel involved in preparing the Final Environmental Statement (FES) can provide important details from the analysis used to develop the FES.
9. In view of the operational difficulties encountered at Surry and San Onofre in setting up reliable thermograph systems, further development work in this area appears necessary.
10. In order to reduce the cost of infrared imaging, consideration should be given to establishing regional programs in which a single agency performs scanning for all the power plants in the area. This might be done in conjunction with the Environmental Protection Agency (EPA), which already has such a capability. From the public's viewpoint, this would have the added advantage of removing the responsibility for at least some monitoring from the utility to an independent agency.
11. As a long-range idea, consideration should be given the possibility of establishing a satellite-borne infrared imaging system capable of scanning all North American power plants on a regular basis. The Aerospace Corporation estimates that such an advanced resources/pollution observation satellite having 3- to 30-m resolution in the IR spectrum would represent a low-risk technology achievable by 1985.¹⁰

2. Ecological monitoring

The following objectives should be considered in the design of a good ecological monitoring program. First, in order to determine whether an impact has occurred, the preoperational ecological conditions at a site must be clearly defined, and this underscores the importance of the preoperational monitoring in the impact assessment process. Secondly, hydrothermal, chemical, and biological parameters monitored coincidentally provide the best opportunity to assist in integrating a comprehensive view of all conditions which may induce changes in the ecosystem. Finally, the monitoring programs should be directed toward addressing specific ecological parameters that appear to be most vulnerable to perturbations (i.e., critical links in the food web) by power plant operations and those parameters that may seriously affect other trophic levels in the ecosystem. With these general comments as background, the following more specific recommendations are offered.

1. Proper selection of monitoring stations during the preoperational period should be made within the following framework. All monitoring stations should have comparable physical characteristics (velocity of water, depth of water, and bottom sediment types) and

comparable chemical characteristics (salinity, pH, NO_3 , PO_4 , O_2), which directly affect the type of biological communities at the location. Stations should not be placed at the mouths of rivers or creeks or be in close proximity to areas affected by sewage effluents or toxic industrial wastes. Stations should be located predominately in control and stress areas close to the power plant because near-field effects are more easily assessed. If stations are properly selected during the preoperational period, then there will be no need to eliminate or add stations at a later time, and a high degree of consistency in monitoring will be maintained from preoperational through operational periods.

2. The uniqueness of the aquatic system associated with each nuclear power plant makes consideration of site-specific designs for monitoring programs an unavoidable necessity. Variations that may exist among aquatic ecosystems include differences in the importance of various trophic levels (i.e., predominance of phytoplankton or macrophytes as primary producers), behavior and interaction of species (predator-prey), and energy flow dynamics into and out of the system and between trophic levels. For example, in a system where phytoplankton densities are low and the benthic community represents a major component of the food chain, the monitoring program design should reflect this relationship and emphasis should be directed toward sampling the benthic community. In addition, before monitoring programs are designed for each aquatic ecosystem, site-specific characteristics related to climate and the type of system that might limit sampling during certain seasons must be considered. Monitoring programs designed for open ocean systems are plagued by sampling problems distinct from those associated with a lake or river system. Likewise, nuclear plants located in the northern latitudes are faced with ice formation problems not encountered at plants in warmer latitudes.
3. An intensive quantitative and qualitative monitoring program for a period of three to five years could be performed, assuming that the generating station operates at commercial levels for a period of not less than one year within the designated monitoring period. In a case where multiple units are located at the same site, the monitoring programs should be performed when all units are operating at commercial levels so that changes occurring during periods of maximum thermal discharge can be determined. If, after the three- to five-year period, proper analysis and evaluation of the monitoring data indicate that no significant detrimental changes to the environment have occurred, the monitoring programs should be re-examined and reduced where appropriate, and the monitoring effort may be redirected toward generic-type studies of special problem areas at the site.
4. Design and analysis of monitoring programs should consider trophic relationships among organisms in the ecological system being monitored. As discussed previously, a basic food web model of the aquatic system under investigation should be constructed so that

relationships and interactions between the various trophic level compartments can be determined. Without an understanding of the relationships between compartments, changes observed in an aquatic system following power plant operation cannot realistically be evaluated. In order to assess the interaction among various trophic levels, the ORNL staff recommends that ecological monitoring include the following sampling methods and procedures:

- (a) Monitoring of phytoplankton should include identification and enumeration of the population to the taxonomic level of genus. Data should be reported as the total number of phytoplankton cells per specific volume and as total number of cells of each genus per specific volume. Thus, a change in the community structure from predominantly diatoms and green algae to blue-green genera can be evaluated. In addition to cell counts, ^{14}C analyses could be made to determine the total amount of carbon fixation occurring. Monitoring effort employing both of these procedures should be concentrated in the period from about early spring through mid-fall. Sampling effort during the remainder of the year should be minimal.
- (b) Monitoring of zooplankton and ichthyoplankton should be performed to assess the total density of the zooplankton and ichthyoplankton, and enumeration of predominant genera should be made where possible. Data should be reported as the total number of individuals in each of the predominant genera per volume. In addition, zooplankton data should be reported as biomass (i.e., dry weight of total zooplankton per volume). Monitoring, especially for ichthyoplankton, should be concentrated in the period from about March through October when organisms are abundant.
- (c) Monitoring of benthos should be performed to determine the total density of benthic organisms per area and the density of predominant genera in the community. In addition to density, biomass measured as dry weight of major groups (i.e., bivalves, gastropods, polychaetes, and amphipods) per area should be presented. Where mollusks form a large percentage of benthos, dry weight measurements should be made of meat only, exclusive of shell. Frequency of monitoring should be less than that for plankton because of longer turnover times of the benthos, but the duration of sampling should be similar.
- (d) Monitoring of fish populations should be performed so that catch data are as representative as possible of the relative abundance of species in the power plant area. This may involve sampling with various types of gear (trawl, seine, trap nets, gill nets) in order to obtain representatives of fishes that have varying vulnerabilities to capture. The

selectivity of various gears for the major fish in the ecosystem studied should be determined. Sampling should be conducted inside and outside the thermally stressed area and along various gradients of the thermal plume so that catches can be related to thermal preferences of fish. The sampling frequency and design for fish monitoring should be based on the sampling policies discussed previously (Sects. I.B.2.a and I.B.2.b), which include sampling within quadrats or subplots. Data recorded with each sample should include catch per unit effort of each species, length-frequency of each species, and temperatures at each station. Sampling should be the most intense in the spring and fall, especially in the river systems where anadromous species may be dominant. Sampling effort during the remaining periods of the year, and especially during the winter, could be reduced.

- (e) For each of the predominant species of fish collected in both the control and discharge area, the age class distribution should be determined. Age class profiles of the predominant species collected in the nekton survey should be compared to the profiles of fishes collected in the impingement program to evaluate whether selective impingement of a particular age class is occurring in relation to the age class structure of the fish population in the vicinity of the plant. Age class profiles between the fish collected in the control and discharge areas should also be compared to determine whether specific age groups of fish are differentially avoiding or congregating in the discharge area. If the thermal plume is causing shifts in size classes in the fish population, sampling should be directed to evaluate the implication of these shifts on fish population dynamics in the area of the plant.
5. Sampling methods and analysis should be performed in a consistent manner using acceptable procedures in common use. If sampling or analytical techniques must be modified during the period of monitoring in order to improve on the accuracy of measurements, then a transitional period using both the old and the replacement method should be initiated so that some correlation between the accuracy of the two methods can be assessed. In the monitoring reports, a thorough discussion of sampling methods and materials employed should be presented.
 6. Technical Specification requirements for each plant should be reviewed and evaluated on a regular basis. This evaluation would be based on the results of the analysis of monitoring data collected during the previous one- to two-year period.
 7. Several major modifications should be made in the reporting of monitoring data.

- (a) Monitoring reports should be submitted annually rather than semiannually. Integration of data in a semiannual report is not conducive to an understanding of temporal changes in ecological parameters because it does not examine a complete growth cycle. A sufficient period of time (two to three months) after the termination of each annual period should be allowed in order to give the utility adequate time to evaluate the previous year's operating data.
- (b) Using proper statistical procedures, all monitoring reports should include an analysis of the monitoring data in assessing potential changes between control and discharge areas. Results of the analyses in each annual report should include consistent use of units, symbols, and notations generally employed in the scientific literature. All tables and figures should be completely labelled and self-explanatory.
- (c) Monitoring reports should include statistical analysis of data. All raw data collected at the site should be easily accessible to interested parties.
- (d) The following tables should be included in each monitoring report:
 - (1) daily power generation levels,
 - (2) daily temperatures at intake,
 - (3) daily ΔT s at selected discharge stations,
 - (4) weekly turbidity averages at intake (based on two to three samples per week),
 - (5) weekly averages of number of circulating pumps operating,
 - (6) daily water flows (where applicable to riverine systems).

8. Entrainment mortality (M_e) at all power plant sites should be computed using a standardized method. The following equation is recommended:

$$M_e = \frac{L_i - L_d}{L_i} \times 100 ,$$

where

L_i = percent of live organisms at the intake
 L_d = percent of live organisms at the discharge.¹¹

Unlike other methods commonly in use that evaluate the change in the percent mortality between the intake and discharge, this equation estimates mortality for the number of organisms alive at the intake that are killed as a result of passage through the condensers. While other methods tend to underestimate the percent entrainment mortality, this equation estimates percent mortality of only the live portion of the plankton capable of reproducing. Vital staining procedures should be employed to differentiate between live and dead animals. The entrainment mortality calculation should be performed not only for the composite plankton sample, but for each of the predominant species present in the plankton, because mortality rates can be extremely variable among species. Also, because mortality varies as a function of temperature, salinity, and biocide levels, mortality should be determined under a representative range of plant operating modes.

9. Sampling frequency for impingement during the year should reflect the relative abundance of fish present in the vicinity of the plant. For example, more frequent sampling should be conducted during the spring and fall migratory periods when large numbers of fish may pass by a power plant. Sampling on a regular basis should be conducted during both the day and night period, and several (at least four) 24-hr samples should be collected during the year. During the 24-hr samples, collection should be made near sunrise and sunset to determine if differential impingement is occurring at these times. The following parameters should be monitored in conjunction with the impingement samples: (a) turbidity and temperature at the intake; (b) number of circulating pumps operating; (c) river flow, lake level, or tidal state (salinity) where applicable; and (d) number of units operating at the time of collection. Fish impingement data should be recorded in a consistent format at each sampling period to include: (a) the total number of fish impinged per unit; (b) the total number of fish of each species impinged per unit; and (c) standard modal lengths, size ranges, and age class structure for each of the predominant species present. The monitoring data should be reported separately for each operating unit because impingement can vary greatly in magnitude between identical units. Where applicable fish impingement system is such that fish are being returned to the river alive (i.e., Surry traveling screens), a short-term tag-and-release study should be conducted to determine whether fish are being reimpinged and to estimate the long-term survival of the returned fish (i.e., determined by recaptures in the regular nekton surveys). In addition, at least once during every quarter, screen wash samples should be diverted into a holding tank, and the impinged fish should be held for 48 hr to determine delayed mortality rates.

Impingement samples should be collected intensively over a period of one year when the power plant is operating under optimal levels of power generation or full pumping capacity. After this period, the data should be analyzed and evaluated to determine the effects of

impingement on the local fish population. This evaluation should include a determination of the age class distribution for each of the major species impinged over the year. This age class distribution should then be compared to the age class distribution of fishes collected during the regular nekton sampling program (i.e., gill nets, trawls, etc.). The potential effects of differential impingement of specific age classes of various species should be noted, and the effect on the structure of the fish populations in the system should be evaluated. If, on the basis of this in-depth analysis and evaluation, impingement is found to have no observable effect on the fish population at the site, the impingement monitoring program could be modified to a reduced level.

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