**AN EVALUATION OF ENVIRONMENTAL DATA
RELATING TO SELECTED NUCLEAR POWER
PLANT SITES**

THE DUANE ARNOLD ENERGY CENTER SITE

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August 1976

**DIVISION OF ENVIRONMENTAL IMPACT STUDIES
ARGONNE NATIONAL LABORATORY**

Argonne, Illinois

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by

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Preface

The Office of Regulatory Research, U. S. Nuclear Regulatory Commission, is supporting a program at the Argonne National Laboratory for the evaluation of the data collected by field studies at a number of operating nuclear power plants. The objective is to analyze data from both a disciplinary and a statistical standpoint. Each of the plants chosen is required, by the terms of the licenses granted, to conduct certain monitoring programs. Some plants are running additional programs to serve their own interests. Do such programs meet the interests of ecologists concerned with the protection of biota? What is the precision and accuracy of the results? What decisions are made on the basis of the field data and how valid are such decisions? Answers to such questions would be of great value in establishing the most cost-effective programs for future plants and redesigning the programs for existing plants.

Through the cooperation of the companies operating the plants, the staff is obtaining the data from a number of installations. As the results are compiled the Laboratory plans to prepare an informal report such as this to present the analysis pertaining to each plant chosen. A summary and inter-comparisons of data, together with the Laboratory's recommendations, will then be presented in one or more reports to the NRC.

This, the third of the informal reports, pertains to the Duane Arnold Energy Center site. Similar reports pertaining to the sites of the Zion, Prairie Island, Three Mile Island, and Nine Mile Point plants are envisaged.

Earlier reports issued in this series are:

ANL/EIS-1 *The Kewaunee Nuclear Power Plant Site.*

ANL/EIS-2 *The Quad-Cities Nuclear Power Station Site.*

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Abstract

Analyses were made on 1974-1975 data pertaining to water quality and the use of biocides at the Duane Arnold Energy Center, which began operating in February 1975. The analyses showed no immediate deleterious effects due to plant operations. Although the plant has not been in operation long enough to reveal any long-term deleterious effects, present indications do not lead to a concerned prediction that any are developing.

The data utilized, the methods of analysis, and the results obtained are presented in detail along with recommendations for improving the current monitoring techniques.

The National Water Pollution Discharge Elimination System Permit is intended to control water quality changes so that they are kept within acceptable limits. Nuclear power plants operate under the provisions of these permits. The use of biocides and the release of other chemicals through the cooling system of the Duane Arnold Energy Center have a potential for affecting the water quality in the vicinity of the plant. Under the Technical Specifications of the license, there are requirements that various water quality parameters be measured and the data collected.

These data were evaluated to determine the effectiveness of the surveillance requirements set forth in the license. Incidental to this undertaking is the development of an understanding of the nature and extent of environmental changes occurring in locales disturbed by the effluents from the plant. The results of this evaluation are presented in this report.

THE PLANT

The Duane Arnold Energy Center is located on the west bank of the Cedar River, eight miles northwest of Cedar Rapids, Iowa.

The site encompasses about 500 acres of relatively flat land, which was primarily farmland. Some woodland areas occur close to the Cedar River and its tributary streams and in the two woodlots north of the plant buildings.

INTERACTION WITH THE ENVIRONMENT

A closed-cycle cooling system employing forced-draft evaporative cooling towers is utilized to dissipate the waste heat. River water is used as the dependable supply of water for the Center's normal and emergency cooling operations.

Water is circulated between the condenser and the cooling towers at the rate of about 290,000 gpm. Vapor and drift losses require that about 11,000 gallons per minute (gpm) of makeup water be drawn from the Cedar River.

The blowdown discharge of about 4000 gpm releases elevated concentrations of chemicals to the river body. Use of biocides also results in additions of chlorine and residues to the water body. In the blowdown discharge, corrosion products are likely to be present and therefore added to the Cedar River.

OPERATING HISTORY

The single boiling-water reactor in the Duane Arnold Energy Center is designed to produce a net of 515 MWe. Initial criticality was achieved on March 23, 1974, and commercial operation began on February 1, 1975.

Since the reactor went critical, daily power generation levels have been reported by the utility to NRC. We obtained these data from the NRC Gray Book and made the plot of power generation on a daily basis for the year 1975 (Fig. 1). From this plot it is evident that daily power generation fluctuates over the full range from no output to the maximum level of 475 MWe (the plant output is limited to this level at the current time). The uses of various chemicals and biocides and the releases in the discharge are therefore affected by such operational characteristics.

The average gross electrical output for the last six months of 1974 was 57% of capacity and for the first six months of 1975, 46%. During the whole period the reactor was critical 79% of the time and the generator on line 75% of the time. Large changes in power output could occur over a short time interval and the averages are results of frequent and large changes in power output. No major failures or changes in equipment occurred in this period, and the plant is presumably operating in accordance with the procedures established in the Technical Specifications and Final Environmental Statement.

CHEMICAL ASSESSMENT

PLANT-SPECIFIC CHEMICAL IMPACTS

The Duane Arnold Center represents a typical example of a system with mechanical-draft cooling towers, located on a moderate-sized river, in a temperate climate. Although the proportion of the total river flow used by the plant is small (ca. 3%), it represents the largest fraction of the available water supply used at any plant considered in this series of reports.

Many characteristics of the Cedar River make interpretation of plant interactions with water quality parameters difficult. Much of the river drainage area is highly fertilized and intensively cultivated farmland. A

Fig. 1. Daily Power Generation Levels.

number of small municipalities are located in the drainage area. As a result of erratic and sometime intense farm runoff, the river has a highly fluctuating level of dissolved salts, nutrients and suspended solids. These fluctuations occur as a function both of time and of spatial position along the river. Since land use and farming practices cannot be expected to be constant over a long term, it becomes difficult to determine true background levels for any of the river water parameters. The river variations thus make plant effects on the river very difficult to determine and observable probably only for the most direct or largest effects.

The potential of the Energy Center for affecting water quality lies mainly in a general increase in dissolved salt concentration due to water evaporation. In addition, biocides and sulfate are added, with bicarbonate being displaced by the sulfate. Temperature increases may cause indirect effects such as lowered oxygen levels in the discharge and increased reaction rates involving oxygen in the river.

PREDICTED IMPACTS

The predicted chemical impacts of the Duane Arnold Center are described in the Sections 3 and 5 of the FES.¹ Chlorine is the only chemical used that is regarded as having potentially serious ecological effects. Sulfuric acid is added in relatively large amounts to the cooling water; however, the water does not reach a low pH, and neither the FES nor the Technical Specifications consider the discharged sulfate to be of environmental significance. Yearly use of the acid must be reported, however. The major chemical change between the discharge water and the river water is the multiplication of essentially all river parameters except sulfate and alkalinity (HCO_3) by the cooling tower concentration factor of 2.8. River bicarbonate is replaced by sulfate on an equivalent basis. The predicted average chemical compositions of the blowdown and river composition after mixing (at minimum flow) are shown in Table 1.

In the FES¹ and original Technical Specifications, a maximum limit for total residual chlorine in the discharge was set as 0.1 mg/l for no more than two hours per day and 0.005 mg/l for all other times. In addition, the Technical Specifications set 0.5 mg/l as the maximum concentration allowed at any time. Measurements were to be taken in the discharge canal water before it was released into the river. The operators were given one year to see if these conditions could be met and if any changes would be necessary. Records of chlorine usage were to be kept although not reported to the Nuclear Regulatory Commission.

In a telephone communication, Mr. Keith Young of the Duane Arnold plant operations staff indicated that the model of operation has since been changed and blowdown discharge is held up during and after chlorination periods until the residual chlorine level has dropped to 0.005 mg/l.

An environmental surveillance program was instituted in an attempt to determine if any plant-induced changes in water chemistry relate to recognizable changes in aquatic life in the river. In this program a number of chemical and biological analyses are to be made of the effluent prior to release and at several points in the river above and below the discharge point.

Table 1. Calculated Effects of Cooling Tower Blowdown on Selected Chemical Concentrations in the Cedar River^a

	Cedar River Conc. ^b		Cooling Tower Blowdown ^c	Cedar River Conc. after Mixing ^d
	Range	Average		
pH	7.9-9.5	8.6	7.1 ^e	8.2
Total P	0.48-2.41	1.22	3.29	1.38
Orthophosphate	0.09-1.71	0.79	2.05	0.89
Ammonia N	0.02-1.56	0.50	Most will probably be converted to nitrate and chloramines.	
Nitrate N	0.05-3.85	0.65	1.69	0.73
Nitrate N	0.02-0.03	0.02	0.05	0.02
			or be converted to nitrate.	
Chloride	16.3-19.5	18.1	48.9	20.5
Sulfate	29-43	38	501 ^f	63

^a Except for pH, all values are in mg/liter (ppm).

^b Unless otherwise indicated, values are those obtained during monthly sampling at four stations (see Fig. 2.15 in the FES)¹ during the period April 1971-April 1972.²

^c Except as indicated, values were calculated based on a concentration factor of makeup/blowdown = 2.7.

^d Dilution factor based on minimum river flow = 20.

^e Adjusted to this value by addition of sulfuric acid.

^f Sum of 99 mg/l due to concentration of Cedar River water and 392 mg/l added as sulfuric acid to control pH, and 10 mg/l due to demineralizer waste.

OBSERVED IMPACTS

Chlorine

Chlorine levels in the discharge must be reported to NRC only in the event the Technical Specifications have been exceeded. To date only one excess chlorine release has occurred. In May 1975, the cooling tower basin inadvertently overflowed to the discharge canal during a plant shutdown. The overflow was calculated to have 0.67 mg/l residual chlorine, which was diluted in the discharge canal and slowly decreased with time. Procedures were subsequently changed to eliminate the possibility of such occurrences. Residual chlorine has been detected in the river on only one instance: during an experiment in which the system was chlorinated to a very high level for a prolonged period.

Under the present chlorination procedure, the discharge water is held up for about three hours after chlorination. An analysis is then made before it is discharged to the river. The chlorine level at this time has not exceeded 0.05 mg/l.

Other Chemical Impacts

The discussion of the observed impacts is based primarily on the two available semiannual reports, July-December 1974 and January-June 1975 covering a year's operating experience. The first report also contains material concerning the time from the start of operational testing and commercial operation until July 1, 1974. In addition to the reports, telephone conversations were held with Mr. Keith Young of the Duane Arnold Center operating staff and Dr. D. B. McDonald of the University of Iowa, who is a consultant in charge of the environmental surveillance program.

The results of water quality analyses for five stations in the Cedar River contained in the semiannual reports are of primary interest to chemists. The analyses were made twice every month or once every four months. A list is given in Table 2 for the two sampling intervals. The stations in the Cedar River were two miles upstream of the intake, Station 1; just above the intake, Station 2; 140 feet below the intake in the mixing zone, Station 3; 2500 feet below the discharge, Station 4; and in the discharge, Station 5.

Operating levels of the plant are shown in several graphs in the semiannual reports. However, because of rapid changes in level, the coarse scale of the graphs, and an unknown time of sampling, correlations of chemical properties with power levels can only be very approximate. Changes in temperature between intake and discharge are therefore also of use in attempting to evaluate approximate power levels.

Included in the first report were some statistical analyses, including ranges and means of the parameters both for all data and with the plant on-line only. Also given were several statistical tests of differences between stations, particularly the differences between those upstream and downstream.

From an examination of the averages given in the tables, there are apparent differences in chemistry or temperature between the station in the plant discharge and all other remaining stations. There were no consistent differences between upstream and downstream station pairs. Of 18 parameters that would be expected to be higher, because of plant operations (alkalinity lower), in the mixing zone (Station 3) than upstream, only nine showed the expected behavior and nine were contrary. At 2500 feet downstream (Station 4) five parameters were larger and 13 smaller than either of the two upstream stations. The statistical tests given in the semiannual report (for on-line periods only) showed only temperature, alkalinity and dissolved volatile solids as having significant (95% level) differences between upstream and downstream station pairs. While the behavior was as expected, the lack of confirmation in other parameters, as well as inconsistencies with the discharge station, raises doubts as to the significance of the tests.

Tables of averages were not given in the 1975 report and the present discussion is based on a comparison of individual data values. These data agreed with the 1974 report in that only the discharge showed consistently

Table 2. Water Quality Parameters

General Water Quality Parameters to be Measured Twice Monthly:

DO	Ca hardness	Lignins & tannen
pH	Total PO ₄	BOD
CO ₂	Ortho PO ₄	COD
Total alkalinity	NO ₃	Taste & odor
CO ₃ alkalinity	NH ₄ ⁺	Temperature
Total hardness	Fe	Turbidity
		Color

To be Measured During Spring, Summer and Fall. All general water quality parameters plus:

Cu	Cr ⁺⁶	NO ₂ ⁻
Zn	Mn	Total solids
Hg	Cl ⁻	Pesticides in fish
Pb	SO ₄ ⁻	from two sites, above and below plant

In addition, DO, pH and alkalinity will be determined at each site every four hours over a 24-hour period.

altered values of parameters from those upstream. Changes in the mixing zone (from upstream) were generally small and inconsistent, and downstream there were no obvious changes.

In view of the difficulties found in detecting changes beyond the discharge plume, it was felt that the clearest information could be obtained by limiting the comparisons to the intake and discharge stations. In doing so the largest possible changes are studied with the least ambiguous baseline. Downstream changes must necessarily reflect the discharge changes even though they cannot be directly determined above the normal fluctuation background.

For the purpose of comparison, parameters were selected from the first part of Table 2 (twice-monthly analyses) that might be directly affected by chemical additions (i.e., sulfuric acid or chlorine) and/or that might be expected to be concentrated by the cooling tower factor without further change. Ratios of discharge to intake or differences (discharge minus intake) were calculated and are given in Table 3 for each date of analysis. Also included are average power levels as taken either from graphs or tables in the semi-annual reports, initial water temperatures, and changes in temperature. Since the ΔT varies with season, expected values of ΔT calculated from data in the FES¹ are also given. In addition to the calculated data of Table 3 based on the twice-monthly analyses, Tables 4 and 5 give the complete results of the

Table 3. Comparison of Inlet and Discharge Properties

Date	Power Level, %	T°, °C	Δ T, °C	Expected Δ T, °C	Total Diss. Solids ^a	Total Susp. Solids Ratio ^a	Hardness	Ortho-phosphate Ratio ^a	Alkalinity ^a	Δ pH	NH ₃ ^a	NO ₃ ^a	COD ^a	O ₂ ^a
6-17-74	48	17.6	2.5	4.1	1.1	1.1	1.0	0.8	1.4	+0.6	0	1.0	0.6	1.1
7- 1-74	37	23.1	0.9	1.4	1.0	0.8	1.0	0.8	1.1	+0.3	0	0.6	1.0	1.1
7-15-74	53	26.8	0.2	1.4	1.9	0.9	1.4	2.0	1.0	-	0.7	1.2	0.7	1.1
7-31-74	72	23.5	1.1	1.4	1.25	1.5	0.9	1.0	1.0	-	1.0	0.9	0.9	0.9
8-12-74	99	25.6	7.3	2.5	6.4	3.2	4.5	3.7	0.4	-0.9	8.2	4.1	2.3	0.7
9- 9-74	80	21.2	1.6	3.6	2.6	1.6	1.2	2.0	1.0	-	1.9	1.1	1.9	0.7
10-21-74	85	8.5	8.6	9.7	1.8	2.4	1.6	0.9	1.3	-	4.0	1.6	0.5	0.8
11- 4-74	75	9.4	6.0	9.7	1.9	1.0	1.3	1.4	0.6	-	1.2	2.3	1.0	0.9
11-18-74	82	5.8	10.2	9.7	2.5	16.0	2.0	2.6	0.6	-0.4	2.0	1.5	2.1	0.6
12-30-74	57	1.2	15.0	14.0	2.4	2.4	2.0	1.5	0.2	-0.7	2.7	1.5	-	0.6
1-13-75	60	0	17.0	14.0	1.7	0.8	1.3	1.3	6.7	-	0.5	1.4	0.3	0.8
1-27-75	65	0	-	19.0	2.2	0.7	1.8	1.3	0.5	-	0.3	1.8	-	0.8
2-10-75	0	0.2	-	19.0	-	-	-	-	-	-	-	-	-	-
2-25-75	73	0.2	10.6	19.0	-	128.0	1.1	1.3	0.9	+0.6	0.5	1.5	6.3	0.5
3-10-75	79	0.2	18.4	12.0	2.1	3.9	1.8	1.3	0.6	+0.3	1.3	2.0	4.0	1.0
3-24-75	68	1.6	6.7	12.0	1.3	1.1	1.1	0.9	0.9	-	0.6	0.3	1.4	1.0
4- 7-75	77	12.0	9.4	10.0	2.2	0.6	1.8	1.4	0.9	+0.5	0.2	1.6	0.5	0.8
4-25-75	7	12.0	1.3	10.0	1.2	0.7	1.2	0.8	1.2	-	-	0.5	0.3	1.1
5- 6-75	0	15.5	3.4	6.4	0.9	0.6	1.0	1.1	1.1	-	1.4	0.4	0.7	1.1
5-19-75	49	21.1	5.9	6.4	1.3	0.9	1.5	1.1	0.5	-	0.8	1.5	1.2	0.9
6- 2-75	49	18.2	3.1	4.1	2.8	1.6	1.5	1.6	0.2	-0.8	0.2	2.0	7.7	1.0
6-16-75	0	17.9	-	4.1	0.9	0.6	0.9	0.9	1.1	-	3.0	-	0.4	1.2
6-30-75	0	27.2	-	4.0	0.9	0.5	1.0	0.9	1.1	-	0.3	0.9	2.0	1.2

^aRatio discharge/intake.

Table 4. Quarterly Chemical Analyses, values in mg/liter

Station	Nitrogen as NO ₂	Cl ⁻	SO ₄ ⁼	Mn	Zn	Cu	Cr ⁺⁶	Pb	Hg
August 26, 1974, 25% Power									
1. Lewis Access	0.008	31.0	37.0	< 0.05	-	0.02	-	0.03	1.5
2. Upstream	0.008	35.5	64.5	0.20	-	0.02	-	0.01	< 0.1
3. Downstream	0.010	29.5	67.0	0.35	-	0.01	-	0.03	1.8
4. Comp Farm	0.013	28.0	54.0	0.35	-	0.02	-	0.01	5.7
5. Discharge	0.011	40.5	144.0	0.20	-	0.03	-	0.01	1.8
Ratio 5.2		1.1	2.2						
October 21, 1975, 85% Power									
1. Lewis Access	0.013	31.7	46.5	< 0.05	< 0.01	0.01	< 0.01	0.01	< 1.0
2. Upstream	0.013	25.8	38.0	< 0.05	0.01	< 0.01	< 0.01	0.01	< 1.0
3. Downstream	0.018	25.8	49.0	< 0.05	0.01	0.02	< 0.01	0.01	< 1.05
4. Comp Farm	0.013	22.3	41.0	< 0.05	0.02	< 0.01	< 0.01	0.01	< 1.05
5. Discharge	0.024	27.8	168.0	0.13	0.16	0.01	< 0.01	0.01	< 1.2
Ratio 5.2		1.1	4.4						

Table 5. Quarterly Chemical Analyses, values in mg/liter

Station	Nitrogen as NO ₂	Cl ⁻	SO ₄ ⁼	Fe	Mn	An	Cu	Cr ⁺⁶	Pb	Hg
May 6, 1975										
1. Lewis Access	< 0.01	19.0	33.0	0.12	< 0.5	< 0.01	0.02	< 0.01	< 0.01	2.0
2. Upstream	< 0.01	22.5	32.0	0.03	< 0.05	< 0.01	0.03	< 0.01	< 0.01	2.0
3. Downstream	< 0.01	46.0	28.0	0.03	< 0.05	< 0.01	0.02	< 0.01	< 0.01	2.2
4. Comp Farm	< 0.01	44.0	24.5	0.06	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	1.1
5. Discharge	< 0.01	65.6	23.0	0.63	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	1.1
Ratio 5.2		2.9	0.7							

quarterly analyses, which cover several important parameters. A discussion of the ratios and differences follows.

Examining the ratios, in general it is seen that the expected ratio 2.8 rarely occurs. The replacement of bicarbonate by sulfate should increase the expected TDS slightly; nevertheless the value of 2.8 was exceeded only once, with a value 6.4 on August 12, 1974. Hardness, consisting mostly of calcium and magnesium, and orthophosphate should reflect only the cooling tower ratio, but generally show neither agreement nor consistency other than the generally high values of August 12. Chloride, nitrate, and COD will be affected by chlorination; however, since the relative times of chlorination are unknown, it is difficult to correlate the data given. In particular, it is difficult to explain, aside from error or contamination, the 33 mg/l increase of Cl on May 6, 1975 (Table 5), with the plant at 0 power -- an increase far above any normal addition for chlorination.

According to the FES,¹ the average sulfate increment was expected to be 400 mg/l in the blowdown, corresponding to an increase of 150 mg/l in dissolved solids since carbonate is lost. Use of 2.6×10^6 pounds of sulfuric acid for six months of 1974 and 1.7×10^6 pounds for six months of 1975 correspond to 295 and 193 mg/l for the average discharge of 4000 gpm. This would result in net changes in TDS of 100 and 70 mg/l. The few sulfate analyses available (144, 168, and 22 mg/l) are evidently unrepresentative and while the sulfate must appear in the TDS results, it cannot be uniquely identified. There are, however, no reasons to believe that recognizable environmental effects can occur at the concentration reported.

It is of interest that at relatively high power levels, the oxygen concentration drops substantially, although it also appeared that low initial oxygen concentrations were raised by plant operations. Suspended solid levels apparently are usually increased less than dissolved solids, and often are decreased; however, there are occasional spurts of relatively high concentrations. Sporadic high concentrations of iron may indicate corrosion in the system, but there were no reported increases of Cr^{+6} , which indicate possible condenser corrosion, although the analysis for Cr^{+6} is probably inappropriate for detecting chromium corrosion.

The high concentrations recorded August 12 occurred both at the highest operating level reported and at the highest intake water temperature. These results suggest (on the limited basis of a single occurrence) that the predictions of the FES¹ can be substantially exceeded under the most adverse conditions. In general, however, at lower operating levels chemical effects are well within those limits projected in the FES.¹

ADEQUACIES AND DEFICIENCIES OF THE MONITORING PROGRAM IN DETECTING IMPACTS

Chemical effluents can directly affect water quality and indirectly impact the ecology of the receiving water body. In this section only direct effects have been considered. With regard to these effects, the FES¹ and Technical Specifications set limits on effluents, and if these limits are met, presumably no unacceptable environmental impacts occur.

Acid concentration (pH) is probably an environmentally sensitive parameter, since large excursions from neutral can be quite harmful. It is probable that proper plant operation requires frequent or continuous monitoring of this parameter. If not, a continuous or short-period program should be instituted.

Few, if any, of the remaining parameters are sensitive and should not require monitoring beyond the present program. The high general chemical and temperature levels of August 12 suggest, however, that it might be advantageous to do special monitoring in periods of high plant stress, i.e., high plant loads with high ambient temperatures. Oxygen concentrations should be particularly examined at high exit water temperatures.

Several high iron analyses occurred, suggesting some corrosion. If the source is the condenser tubes, which are stainless steel, chromium in its lower valence states and nickel would be produced, both of which are potentially harmful. Consequently, these two substances should be added to the parameters presently monitored.

The primary source of monitoring information should be based on comparisons of the intake and discharge, preferably at a time interval corresponding to the average transit time of water through the plant. The fluctuations in measurements at other locations make their assessment very difficult and, in any case, cannot give more information about plant effluents than is already contained in the discharge-intake comparison.

The analyses in general appear to be highly erratic, particularly for ratios which would be expected to be constant at a given time. According to Dr. McDonald,² the erratic nature of the plant operations, i.e., quick changes in operating levels, does cause substantial inhomogeneities in the outlet stream and this is undoubtedly part of the problem. Analytical errors probably occur and should be corrected, although they are difficult to identify. Few of the items are sensitive, and consequently high precision is not necessary. Reliability should be the most important requirement.

On the basis of the results reported and discussed earlier, it is not clear that the Duane Arnold Energy Center did have any impact on the chemistry of the Cedar River or that the present environmental surveillance program could detect an impact. Even for parameters, such as temperature, in which changes can be detected (for short distances at least) the impact is difficult to evaluate. While a general knowledge of river water quality is desirable as background, it is difficult to relate this information to plant operations.

As a consequence of the difficulties and uncertainties of the present program, the staff believes a preventative monitoring program would be more effective for environmental protection. Where possible, monitoring should be done before release of a potentially harmful material as is done in the chlorine monitoring program. Other substances considered important or critical should be monitored on a continuous basis since releases are often sporadic and cover short time intervals. Temperature, pH, conductivity, and possibly dissolved oxygen (if sufficiently reliable equipment is available) should be monitored on a continuous basis in the discharge. It is probably not necessary or possible to monitor nickel and total chromium continuously, but since those materials are potentially harmful corrosion products, tests should be conducted on a periodic or a selected time basis. Excesses could be quickly corrected or if necessary, plant operations reduced.

Records of the analyses should be kept and be available to appropriate personnel, but reporting to authorities should only be necessary if set limits are exceeded.

References

1. "Final Environmental Statement related to the Operation of Duane Arnold Energy Center," Atomic Energy Commission, Directorate of Licensing, Docket No. 50-331, March 1973.
2. D. B. McDonald, "Cedar River Ecology Study, Annual Report, April 1971-April 1972."