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Before and After Case Studies:

Comparisons of Water Quality following Municipal Treatment Plant Improvements

BEFORE AND AFTER CASE STUDIES: COMPARISONS OF WATER QUALITY FOLLOWING MUNICIPAL TREATMENT PLANT IMPROVEMENTS

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PREFACE

This project was conducted by HydroQual, Inc. (1 Lethbridge Plaza, Mahwah, New Jersey 07430), under contract with the United States Environmental Protection Agency (USEPA), Facility Requirements Division, Office of Water Programs Operations.

Dr. Robert V. Thomann at the time of the study was a partner with HydroQual. He is presently associated with Manhattan College. The authors wish to acknowledge the following individuals who contributed in various ways to this project: Dr. Donald J. O'Connor of HydroQual for providing the technical review of this project; Ms. Maureen Casey of HydroQual, who assisted in data collection and analysis efforts; Mr. John Maxted (USEPA, Project Officer); Mr. John Hall (USEPA), Mr. Robert Foxen (Foxen and Associates) for providing valuable assistance, guidance and insight for this study.

We would also like to acknowledge the numerous persons summarized in Appendix A for taking time out of their busy schedules to organize the information sources and to help the authors understand each case study.

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BEFORE AND AFTER COMPARISONS OF WATER QUALITY
FOLLOWING MUNICIPAL TREATMENT PLANT IMPROVEMENTS

EXECUTIVE SUMMARY

More than 25 years have passed since the initiation of the first Federal Waste Treatment Plant Construction Grants Program. In this time, the number of secondary treatment facilities has increased to some 7800 while advanced treatment facilities have increased to about 2700. By the year 2000, it is expected that there will be about 11,900 and 7400 secondary and advanced treatment facilities, respectively.

To date the effectiveness of most treatment facilities is judged on whether the facility meets the effluent limits of the National Pollution Discharge Elimination System (NPDES) permits. Since the goal of waste treatment facilities is to improve the quality of the nations waters, it is also necessary that the effectiveness of treatment plants is judged in terms of water quality improvements gained subsequent to improving treatment levels. Evaluation of water quality improvements subsequent to upgrading treatment levels from secondary to advanced treatment is especially important since the incremental cost of this upgrade is relatively large compared to the amount of pollutant removed.

This study is directed toward the overall issue of determining before and after responses of river systems following installation of improvements in municipal wastewater treatment facilities. The basic objectives of the study are threefold:

a. To determine the extent of the data base for water quality before and after improvements and compile such data.

b. To compare the before and after data to determine changes in water quality after treatment improvements.

c. To evaluate the ability of calibrated wasteload allocation water quality models to predict water quality after improved treatment.

Output from the study includes actual measured water quality improvements after construction of an upgraded treatment facility. The study also provides an assessment of the accuracy of water quality models used as planning tools.

Data Availability

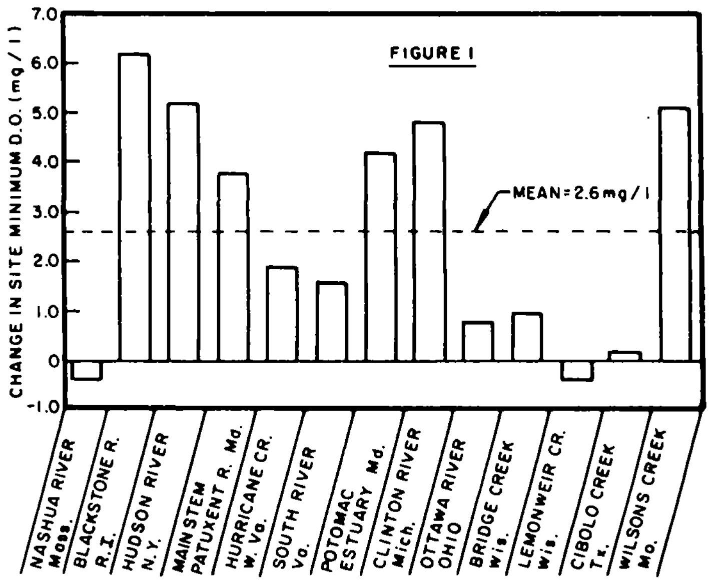
Thirty one states, four USEPA regional offices and four regional planning boards were contacted for before and after data. Of these numerous contacts, no individual agency had a complete compilation of water quality, biology, water use, model and publically owned treatment works (POTWs) effluent data necessary to perform a detailed before and after comparison. A partial data base, however, was compiled from 52 water bodies. These data sets were screened, and rivers where background flows and inputs were equal in the before and after settings were selected so that the only influence on water quality was the treatment change. Data sets from 13 of these water bodies were considered adequate for review. These 13 water bodies and the associated changes in treatment of the POTWs discharging to them are summarized in Table 1.

TABLE 1

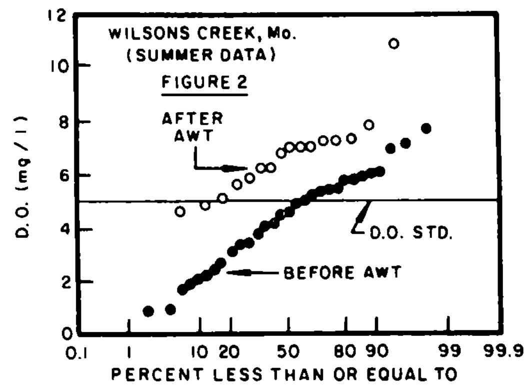
River	State	Facility	Treatment Change
Nashua	MA	Fitchburg East.	Secondary to Advanced Treatment
Blackstone	RI	Woonsocket	Primary to Secondary
Hudson	NY	Albany Area	Primary to Secondary
Patuxent	MD	Laurel Pkwy.	Secndary to Advanced Treatment
Hurricane	VA	Hurricane	Upgrade to Secondary
South	VA	Dupont (ind.)	Secondary to Nitrification
Potomac	MD	Blue Plains	Secondary to Advanced Treatment
Ottawa	OH	Lima	Secondary to Nitrification
Clinton	MI	Pontiac, Auburn	Secondary to Advanced
Bridge	WI	Augusta	Secondary to Nitrification
Lemonweir	WI	Tomah	Secondary to Nitrification
Cibolo	TX	Odo J Riedel	Upgrade to Secondary
Wilsons	WY	Springfield S.W.	Secondary to Advanced Treatment

Water Quality Changes

Data from intensive water quality surveys on 10 of these 13 water bodies show increases in dissolved oxygen of between 0.8 and 6.1 mg/l at the point of minimum dissolved oxygen after treatment improvements (Figure 1). Before treatment was upgraded, minimum dissolved oxygen concentrations were below the dissolved oxygen standards in 12 of the 13 rivers. After treatment was upgraded, nine of the rivers had minimum oxygen concentrations above the standard or were within 1.0 mg/l of it.



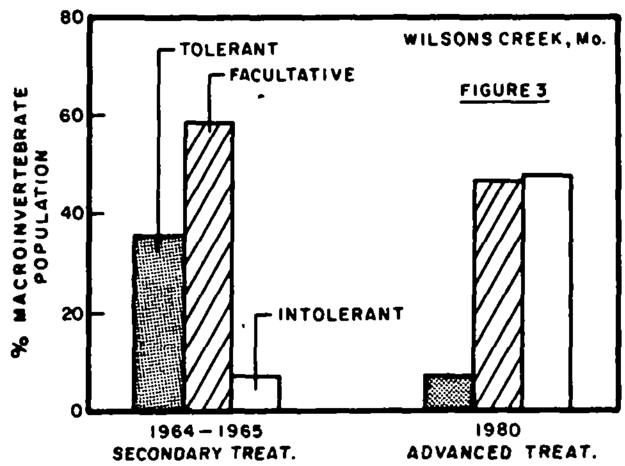
In four of the rivers where monthly sampling data are available at routine monitoring stations, dissolved oxygen standards were violated between 20 and 60 percent of the time before treatment was improved. In the same four rivers (Wilson, South, Clinton and Blackstone), after treatment was improved, violations of standards decreased to between 1 and 15 percent of the time. Figure 2 presents the effect of treatment on the dissolved oxygen levels at the sag point in Wilsons Creek on which treatment was upgraded from secondary to advanced levels.



Before and after stream quality data also show decreases in maximum biochemical oxygen demand (BOD_5), ammonia, and un-ionized ammonia levels subsequent to improved treatment. BOD_5 concentrations decreased by 15.0 mg/l or more in 5 of the 13 rivers. In two of the rivers, ammonia concentrations decrease by approximately 20.0 mg/l after installation of advanced treatment facilities.

Biological Changes

The amount of biological before and after data available for review is inadequate to make conclusions on the effect of treatment changes on instream benthic organisms. For two cases where before and after comparisons can be made to assess the effect of treatment changes on the ecosystem, results are mixed. Wilsons Creek (Figure 3), on which the only point source load was upgraded from secondary to advanced treatment, shows a shift from pollution tolerant benthic organisms to more sensitive organisms. On the Ottawa River, where the Lima POTW was upgraded to nitrification (and two industrial discharges were unchanged), benthic diversity and numbers remain depressed. Data from other streams, although much more qualitative, indicate a shift toward healthier benthic macroinvertebrate communities when there is a major improvement in water quality.



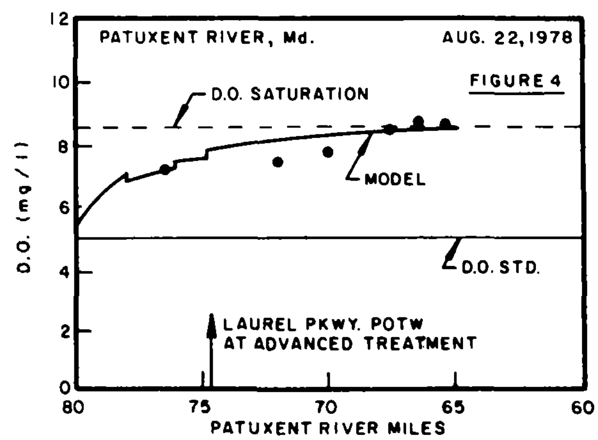
Available data to assess fish populations after treatment upgrades are sparse; however, qualitative information available show an increase in fish population in Wilsons Creek and the Ottawa river. No quantitative data, such as fishing angler, swimming, or site attendance days were available for any of these rivers to assess changes in recreational activity. Although the data were sparse, it appears likely that in some cases, factors other than pollutant loadings from treatment plants such as upstream sources and physical stream habitat prevented biological improvements from taking place.

Water Quality Modeling

Mathematical water quality models have evolved from the early 1900s to become tools used by many present day water quality planners to make wasteload allocation decisions. Models have grown from simple analytical equations to multi-segmented, computer-based solution techniques requiring large amounts of memory and high speed computers.

The accuracy of models to date is generally evaluated during calibration or verification analyses. Rigorous evaluations have not been performed to show the accuracy of calibrated models after a treatment facility has been upgraded. The compilation of before and after data discussed earlier provides information necessary to verify the ability of models to predict changes in dissolved oxygen concentrations in response to POTW treatment improvements.

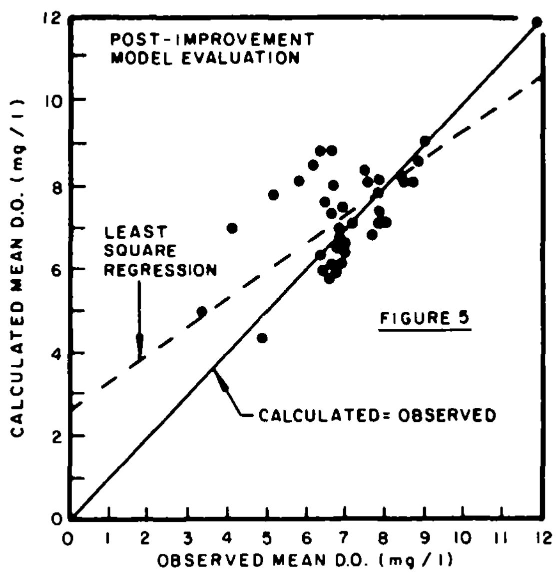
Sufficient information is available for six water bodies to permit an evaluation of the mathematical models used in the wasteload allocation procedures. These six water bodies are the Patuxent River, Wilsons Creek, Hurricane Creek, Cibolo Creek, Hudson River and the Clinton River.



Testing of each model is performed in this study by setting up each model for the appropriate "after treatment change" river conditions (flow, temperature, POTW effluent). Model reaction rates for carbonaceous biochemical oxygen demand (CBOD), oxidation, nitrogenous biochemical oxygen demand (NBOD) oxidation, sediment oxygen demand (SOD), photosynthesis and oxygen reaeration are identical to those rates used in the original wasteload allocation study. Figure 4 presents a comparison of computed model results and observed dissolved oxygen data after treatment was upgraded on the Patuxent River. Similar results are obtained for the other five rivers.

Root mean square (RMS) errors, which are a measure of the deviation of the model from observed data, serve as a quantitative measure of model accuracy in reproducing after data. In post-improvement testing, RMS errors range from 0.0 to about 2.0 mg/l. Average error of 0.9 mg/l is only slightly larger than the RMS error 0.7 mg/l associated with calibration of these six models, indicating that the models perform fairly well in predicting water quality.

An additional measure of the models ability to reproduce post-improvement data is the correlation of observed and calculated mean dissolved oxygen concentrations. This analysis (Figure 5) suggests that post-improvement models have a tendency to over-estimate dissolved oxygen levels at concentrations less than 7.0 mg/l. This result indicates that the RMS errors are generally in the direction of over estimation of dissolved oxygen concentrations.

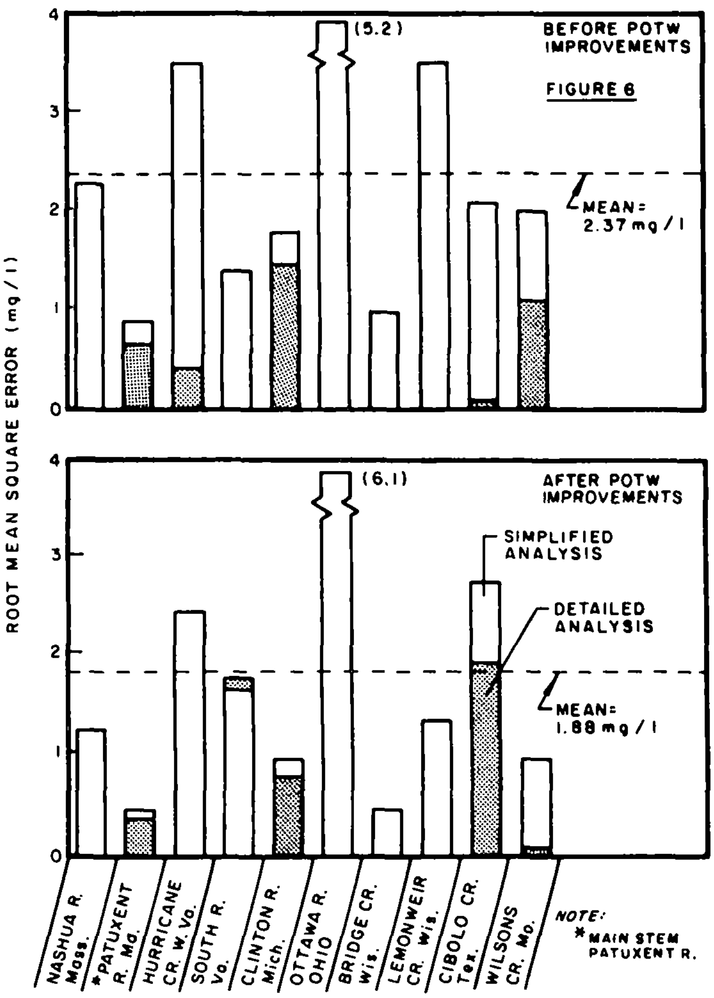


Evaluations are also made as part of this project to discern changes in instream CBOD and NBOD oxidation rates after installation of advanced waste treatment (AWT) at the POTWs. In general, CBOD oxidaton rates after improved treatment are approximately 60 percent of the pre-improvement oxidation rates.

The NBOD (nitrification) oxidation rates, however, do not show similar trends. Nitrification rate changes are dependent on the water body of interest and show no general trend toward increasing or decreasing after improvements to treatment facilities.

Simplified Water Quality Modeling

A simplified approach to performing wasteload allocations for effluent dominated streams is tested during this project against before and after data. Testing is performed for two criteria; the utility of the model as a decision making tool and the accuracy of the model in predicting instream dissolved oxygen concentrations. Ten rivers are included in this analysis.



The simplified technique was found to be an accurate decision making tool for planning treatment upgrades from secondary treatment to nitrification in 9 of 10 cases analyzed. The simplified method is a less accurate planning tool for predicting water quality improvements from treatment beyond nitrification. Quantitatively, the simplified technique results in RMS errors that are 50 to 200 percent higher than RMS errors developed from more rigorous modeling analyses (Figure 6). The average RMS error for the 10 river analyses is approximately 2.0 mg/l.

CONCLUSIONS

The analyses performed in this report lead to the following conclusions concerning operational conditions; water quality models; long term water quality changes; and simplified water quality model evaluations.

Pre- and Post-Operational Conditions

1. There is an apparent lack of data on water quality, ecosystem response, and changes in water use following the installation and operation of improvements in municipal waste treatment facilities. Of 37 states, 5 USEPA regional offices and 6 regional planning boards that were contacted, there was no case where a complete data set (chemical, biological, use) was available. Regulatory agencies, however, are beginning to recognize this lack and in some instances are planning post-operational evaluations.

2. From an initial data base of 52 water bodies, 13 were appropriate for post-operational evaluation. Ten of the thirteen water bodies showed increases in dissolved oxygen concentration after treatment upgrade. Short term (less than five years after upgrade) changes in minimum dissolved oxygen averaged approximately a 2.6 mg/l increase (-0.5 to 6.1 mg/l).

3. In the 13 water bodies, decreases in maximum ammonia concentrations of approximately 5 mg/l and decreases in maximum un-ionized ammonia concentrations of tenths of an mg/l were observed.

4. Before treatment was upgraded, dissolved oxygen standards were violated in 12 of the 13 rivers. After upgrade, nine of the rivers were above or within 0.5 to 1.0 mg/l of the dissolved oxygen standard. Four of the rivers were 2 mg/l or more below the standard.

5. Dissolved oxygen standards were not met in four rivers after upgrade due to: (a) influences from upstream or other point sources, or (b) large diurnal dissolved oxygen fluctuations.

6. No significant change in the increment of dissolved oxygen from mean to minimum concentrations was observed in the water bodies between pre- and post-improvement conditions. Based on these data, a dissolved oxygen concentration of approximately 1.0 mg/l could be subtracted from the mean value to approximate a minimum value.

7. The effectiveness of dissolved oxygen improvement was inverse to the river flow and ranged from approximately 0.01 mg/l dissolved oxygen increase/1000 lbs ultimate oxygen demand removed per day at 10,000 cfs river flow to approximately 3 mg/l dissolved oxygen/1000 lbs ultimate oxygen demand removed per day at 2 cfs. These observations qualitatively confirm general mathematical models of water quality and indicate that for a unit removal of oxygen demanding material, there is a larger increase in dissolved oxygen in a smaller stream than for a larger stream.

8. For four rivers where data were available, dissolved oxygen standards were violated between 20 to 60 percent of the time before additional treatment was provided. After improvement in treatment, dissolved oxygen standards were violated 1 to 15 percent of the time.

9. Effluent five day BOD_5 from 38 secondary treatment facilities averaged 19.1 mg/l (standard deviation(s) = 16.3 mg/l) during summer intensive survey periods. Effluent five day $CBOD_5$ from 24 of the facilities averaged 10.3 mg/l (s = 6.4 mg/l). These data may indicate that secondary treatment facilities achieve effluent BOD_5 concentrations during summer periods which are less than the 30 mg/l concentration typically used to define secondary treatment effluents. The data further suggest that nitrification may be occurring in the BOD_5 test and that inhibition of the BOD samples to yield $CBOD_5$ concentrations may more accurately represent plant performance.

10. Similarly, for the treatment facilities with nitrification processes, effluent BOD_5 averaged 11.5 mg/l (s = 11.8 mg/l) but $CBOD_5$ data from seven plants averaged 4.8 mg/l (s = 8.2 mg/l).

11. No significant relationship was obtained for the ratio of ultimate CBOD to BOD_5 or $CBOD_5$ for 144 POTWs. $CBOD_{ult}/BOD_5$ averaged 2.5 (s = 1.5) and $CBOD_{ult}/CBOD_5$ averaged 2.8 (s = 1.2).

12. For two cases where before and after comparisons could be made for the effect on the ecosystem, the results were mixed. One stream showed an improvement from 6 percent pollution intolerant macroinvertebrate species to 47 percent following treatment upgrade. A second stream showed no improvement in macroinvertebrate diversity and number of taxa after upgrade of a municipal plant. In this river, however, discharges from two nearby industrial plants have remained unchanged.

13. Data compiled from an extensive study of 53 Wisconsin streams indicated an approximate linear relationship between a biotic index and dissolved oxygen over the range of dissolved oxygen from 3.0 to 11.0 mg/l. This is in contrast to the prevailing hypothesis that the ecosystem is not responsive to increases in dissolved oxygen above approximately 5.0 to 6.0 mg/l. It should be noted, however, that this information is not presented to suggest a revision to existing dissolved oxygen criterial. Any such revision would require detailed assessment of biotic index conditions during periods of critical flow and temperature.

Water Quality Mathematical Model Evaluations

1. Sufficient information was available for six water bodies to permit an evaluation of the mathematical models used in the wasteload allocation process. Root mean square errors of dissolved oxygen between the model and the data during calibration and verification analyses averaged approximately 0.7 mg/l. The RMS errors between model calculation and observed post-improvement data averaged 0.9 mg/l.

2. Comparisons of calculated versus observed mean dissolved oxygen indicated that in the post-improvement phase, the model calculations on the average reproduced the observed data but tended to over-estimate the dissolved oxygen in individual cases.

3. An analysis of instream coefficients of oxidation of CBOD and NBOD for seven cases of before and after treatment improvement showed no clear trend.

Long Term Water Quality Changes

1. The ultimate level of water quality improvement for the long term (i.e., over 10 to 20 years) must be measured from expected water quality at POTW design loads and drought flows, but with no POTW upgrade.

2. For four rivers, the improvements in POTW (at design loads) are estimated to result in substantial improvement in dissolved oxygen over levels without increases in treatment. All rivers are estimated to violate dissolved oxygen standards without improvements. Following upgrade at design levels, all four rivers are estimated to be above 4.0 to 5.0 mg/l dissolved oxygen and at least 20 miles of anaerobic stream is prevented from occurring.

Simplified Water Quality Model Evaluations

1. As a result of evaluation of simplified wasteload allocation techniques, the simplified wasteload allocation reproduces wasteload allocation decisions made by other analyses up to a level of secondary treatment plus nitrification. Beyond this level of treatment, the method results in different facility decisions in at least three of nine cases. Beyond nitrification, the method performs poorly because of the small reductions in pollutant loadings which are attained by these additional levels of treatment.

2. Although the method is noted to perform well in some cases, and poorly in others, the absolute dissolved oxygen levels that are predicted using this method are not nearly as accurate as those concentrations predicted using more resources intensive methods.

RECOMMENDATIONS

From this work the following recommendations are offered:

1. Additional data should be collected for before and after comparisons of water quality following POTW improvement to further document observed changes and improve water quality model credibility.

2. The before and after studies should include collection of biological, ecosystem characteristics and water use data, as well as the physical/-chemical data that is normally collected for the purpose of calibrating a model. These data are all useful in determining whether pollution sources or physical habitat factors are important in attaining biological or water use goals.

3. Although the simplified modeling methodology performed well as a tool for determining treatment requirements in some instances, the method tended to under predict instream oxygen concentrations. Because of this, further investigations should be made of the coefficients recommended by the procedure to improve its preditive capability.

SECTION 1.0

INTRODUCTION

Water quality mathematicals are generally used to evaluate the need for AWT facilities. These models, after calibration and/or validation, are used to project water quality conditions after AWT projects are built. Actual instream water quality, after construction of the facility, is very rarely monitored and compared to pre-improvement water quality.

1.1 The Need for Before and After Comparisons Following Municipal Treatment Plant Upgrade

More than 25 years have passed since the initiation of the first Federal Waste Treatment Plant Construction Grants Program in 1956 under the Water Pollution Control Act. Since that time, wastewater treatment systems have been built to improve and/or maintain desired water quality in streams and rivers, estuaries and lakes. At present, there are some 7800 secondary treatment plants and some 2700 plants that treat to levels beyond secondary.[1] By the year 2000, it is projected that there will be about 11,900 secondary plants and 7400 advanced treatment facilities.[1] Further, since 1973 about 24 billion dollars have been expended on construction of new facilities. With these expenditures, one can legitimately ask, "What has been the effectiveness of this treatment plant program? i.e., What has been the result of this effort and expenditure?"

Recognizing that the response of the water body in terms of improved quality and subsequently improved water use is central to the success of water pollution control programs, it is important that information be obtained on the effectiveness of treatment in meeting water quality standards. Assessment of this effectiveness requires a two-staged evaluation. First, the analysis phase performed by a regulatory agency verifies the need for the upgrade of a POTW. Second, the actual effectiveness of treatment in improving or maintaining water quality, the aquatic ecosystem and associated water use is determined after construction of the treatment works. Without the second stage, the questions concerning water use benefits cannot be answered.

In many instances, the level of treatment for the facility is based in the analysis phase, on the use of water quality--wasteload allocation models. Such models are utilized to determine the allowable discharge load and the discharge permit requirements. The effectiveness phase involves water quality studies of the river after the upgraded facility is operational. These before and after evaluations for a POTW can be thought of as being composed of two components: (a) an analysis of the actual water quality and ecosystem response and associated water use response, and; (b) an analysis of the effectiveness of the allocation model framework in predicting observed water quality responses.

The first component addresses two questions. Did the installation of the improvement in the wastewater treatment facility, in fact, meet the targeted water quality standards? What is the performance record of treatment in improving water quality and/or meeting water quality standards? The second component also addresses two questions. Have the mathematical models utilized for establishment of treatment levels proved reliable? Is the model performance satisfactory?

Particular interest in the effectiveness of POTW improvements centers about improvements beyond secondary treatment to advanced treatment AWT. It is generally accepted that eliminating raw discharges through primary treatment significantly improves water quality in most cases. However, as the level of treatment increases, the need to assess the effect of higher levels of treatment on the water body also increases. This is due primarily to two reasons:

a. At secondary treatment and beyond, the effluent concentration of residuals (e.g., BOD, suspended solids, ammonia) decreases to low levels and hence, associated water quality changes can be difficult to perceive and assess.

b. The marginal costs of treatment (i.e., the change in cost per change in constituent removed) increases dramatically (by about 10 times) when going from secondary to AWT.

It is for these reasons that Congress has expressed increasing concern over whether expenditures for the construction of advanced wastewater treatment facilities results in signficant water quality improvements. In addition, criticism of water quality based standards used to justify AWT processes have raised questions about whether water quality based models and analyses can accurately predict improvements claimed for a particular treatment process. In response to these concerns, a detailed review of the technical justification of AWT facilities is carried out by the Agency under authority of a Congressional directive and in accordance with Program Requirement Memorandum (PRM) 79-7. The USEPA also encourages states to use available federal funds to monitor water quality after completion of municipal wastewater treatment plants. These so-called "before and after" studies can be used to both verify the assumptions used in modeling, to predict water quality impacts, and to document the water quality improvements.

1.2 Purpose and Objectives of Study

This study is directed toward the overall issue of determining the before and after response of aquatic systems following the upgrade of treatment at POTWs. The objectives are to:

a. determine the available data base that permits before and after comparisons;

b. determine changes in water quality under comparable conditions following POTW upgrade;

c. evaluate changes in the aquatic ecosystem from POTW improvements;

d. determine changes in water uses associated with the treatment plant improvement;

e. compile information on the analyses and model used to justify the POTW upgrade; and,

f. compare the model projections of water quality made before the POTW improvement with actual water quality monitored after the upgraded POTW was operational.

1.3 Scope

The primary focus of this project addresses the impact of CBOD and ammonia on dissolved oxygen concentrations in streams where data on pH, temperature, and ammonia are available; water quality trends associated to ammonia toxicity are also presented. Water quality responses of lakes relate primarily to the problem of nutrient reduction for control of eutrophication, and hence constitute a separate problem. Control of point source industrial discharges, nonpoint runoff, storm water, and combined sewer overflows (CSOs) are also important issues in natural water systems. However, the scope of the study would have expanded significantly beyond available financial resources to evaluate the effectiveness of reducing these sources on changes in water quality. Therefore, only POTW sources were examined. Finally, from a water quality point of review, the emphasis of this study was on dissolved oxygen and nitrogen components since these variables are most often used as the indicator standards of water quality that must be met by increased treatment.

1.4 Benefits of a Before and After Analysis of POTW Improvement

Analyses of the data from before and after a POTW improvement, provides an assessment of the actual, not predicted, effectiveness of wastewater treatment systems in improving and maintaining water quality and water use. The analysis also provides an assessment of the reliability of the primary planning tools (mathematical water quality models) to project future water quality.

Benefits of before and after analyses of the performance of both POTWs and wasteload allocation models are:

a. assistance in water use attainability analyses;

b. a firm, defensible and quantitative description of actual treatment plant performance in improving water quality, ecosystem response and water use;

c. improvements in future modeling through evaluation of actual performance of the predictive capability of contemporary water quality models;

d. identification of problem areas in treatment effectiveness and model performance, and;

e. compilation of data for use in wasteload allocation analyses for projection of responses under similar treatment and environmental conditions.

SECTION 2.0

BEFORE AND AFTER IMPROVEMENT DATA COLLECTION

Before and after improvement data is intended to provide a complete overview of water quality changes following improvements to municipal treatment facilities. In addition, the data is intended to provide an overview of the benefits, to the biological community and to the public which results as a function of any water quality changes.

2.1 Methods of Collection

At the initiation of this project a substantial effort was directed toward developing a data base of information for use in assessing changes in water quality and/or water uses associated with upgrading treatment works from secondary treatment to advanced treatment levels. Since no data were immediately available, this effort involved contacting state and federal agencies to obtain pertinent information. A total of 31 states, 4 regional USEPA offices and 4 regional planning boards were contacted during March through July of 1982.[2,3]

During this period, some 97 people at the various agencies provided information. A list of these contacts is presented by state in Appendix A.

2.2 Parameters Requested

Water chemistry, treatment plant effluent concentrations, biological quality, recreational use and wasteload allocation modeling data were requested from water bodies on which a treatment facility was upgraded from secondary treatment to AST or AWT. A detailed list of parameters requested is presented in Table 2.1.

TABLE 2.1

PRE- AND POST-OPERATIVE PARAMETER REQUEST LIST

Water Chemistry

1. Dissolved oxygen
2. BOD
3. Temperature
4. pH
5. Nitrogen forms
6. Un-ionized ammonia
7. Phosphorus
8. Chlorophyll

POTW Effluent

1. Treatment type
2. Flow (actual, design)
3. BOD
4. Nutrients

Wasteload Allocation Modeling

1. Model calibration results
2. Model wasteload allocation results
3. Model output listing

Biology

1. Fish populations
2. Benthic macroinvertebrates
3. Invertebrate diversity indices
4. Habitat

Recreational Use

1. General asthetics
2. Angler days
3. Swimming days
4. Shellfish harvesting days

General

1. Stream depth
2. Flow (actual, 7Q10)
3. Sampling station locations

The optimum situation was to obtain data for all parameters listed in Table 2.1, both before and after a treatment facility was upgraded. Data were requested for intensive surveys conducted at or near critical flow and temperature conditions on effluent dominated streams. Water quality monitoring data collected throughout the transition period were also requested if the data were collected near the dissolved oxygen sag point.

2.3 Data Collection Results

Thirty one states (Figure 2.1) along with four USEPA offices and four regional planning boards were contacted by HydroQual. Of those contacted, eight states had no AST or AWT facilities or had no post-improvement data. Eighteen of the thirty states had the appropriate data. Five of the states had no data but were planning to collect post-improvement data in 1982, and four states which had data were also planning 1982 field surveys.

Eventually, a data base covering in excess of 52 water bodies and some 214 references was constructed. A complete summary of these data sources is presented by state and water body in Appendix B.

Upon receipt of each reference, HydroQual reviewed the information for those parameters listed in Table 2.1. Follow-up requests were then made until the majority of data existing on a particular stream had been collected and reviewed.

All data sets were then screened and of the 52 water bodies with data, a total of 13 water bodies contained data appropriate for a partial evaluation. This evaluation focused primarily on water quality responses since data on water use changes were generally not available. The following evaluation criteria were used to screen information and develop complete case histories.

a. Pre- and post-operational water chemistry data should exist.

b. Data should originate from intensive field sampling surveys conducted at or near critical conditions.

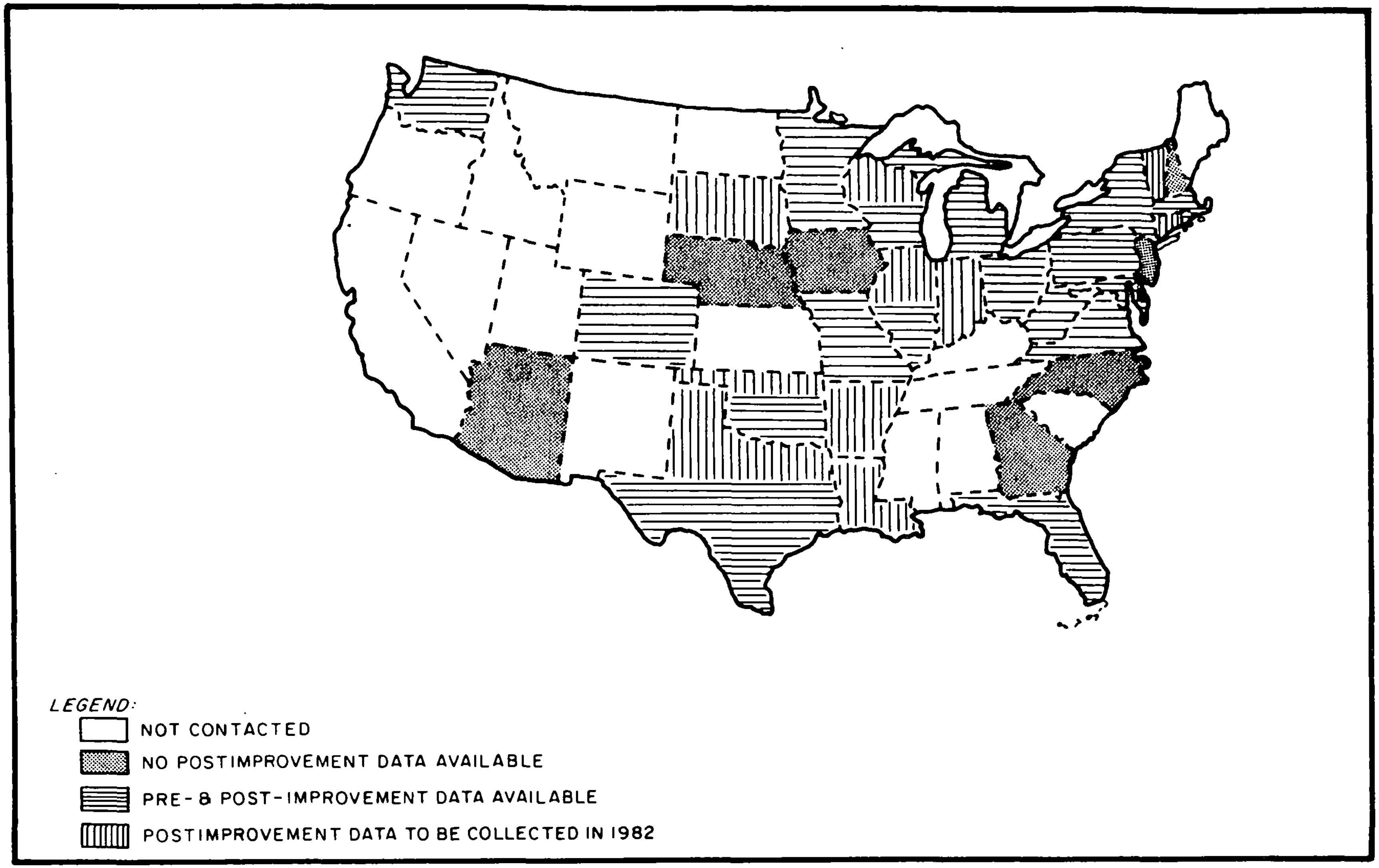


Figure 2.1

Results of Postimprovement Data Collection Survey

c. If surveys were not conducted at critical conditions, before and after surveys should be conducted at similar flow, temperature, sunlight, and nonpoint source loading conditions.

d. Other point sources discharging to the river should be at similar effluent pollutant loadings during both the before and after surveys.

e. Pre-improvement discharges to the river should be treating wastewaters to a minimum of primary treatment and preferably should be at secondary treatment.

f. Post-improvement wastewaters discharged to the river should be treated to secondary levels or greater.

The purpose of imposing such criteria was to be able to assess the effect of improved treatment on water quality without other point or nonpoint sources influencing the change in water quality.

2.4 Data Analysis

Data collected for the 13 water bodies were reduced into individual case histories presented in Appendix C. These case histories contain background information on changes in water quality, biology, mathematical modeling results, and wasteload allocations on a site by site basis. Because of the large number of sources of data used to construct the case histories, HydroQual is not able to reference each source of data on an individual basis. However, all data used in the case histories originate either from the data sources listed in Appendix B or from personal conversations with the points of contact listed in Appendix A.

SECTION 3.0

EVALUATION OF SHORT TERM WATER QUALITY CHANGES

The effectiveness of treatment processes beyond secondary treatment in improving or upgrading the nations waterways has been in question in recent years. This section of the report reviews field sampling data collected before and after a POTW has been upgraded for 13 water bodies throughout the country. Since many of the upgraded treatment facilities are designed for the expected year 1990 or year 2000, influent flows and field sampling data are available for a period covering no more than a few years after the facility was upgraded, and these changes in water quality are referred to as short term changes. These short term water quality improvements may therefore, be based on POTWs which are presently underloaded. Alternatively, changes anticipated by the years 1990 or 2000 when POTWs are at full design flow are referred to as long term changes.

Because most POTWs are not at full design flow, the analysis of long term improvements requires the use of projection water quality models to simulate dissolved oxygen concentrations with and without the facility improvements. When POTWs are at full design flows, long term improvement analyses can be evaluated directly from water quality data. A water quality model evaluation of long term improvements is presented in Section 5.0 of this report.

3.1 Intensive Survey Water Chemistry

Water quality data collected both before and after a treatment facility has been improved were gathered and reviewed in detail as discussed in Section 2.0 of this report. Detailed case history descriptions of these 13 water bodies are presented in Appendix C. Appendix C also contains graphic summaries of pre- and post-improvement data including stream flow, mass loading, and instream concentrations of dissolved oxygen, BOD_5, ammonia and nitrate. Before and after studies were chosen so that background and other point and nonpoint loadings were similar in both surveys and water quality changes were caused mainly by changes in treatment levels.

The 13 water bodies are listed in Table 3.1. Dissolved oxygen data collected both before and after individual treatment works were upgraded, and are presented graphically on Figures 3.1, 3.2, 3.3, and 3.4 for the 13 water bodies.

Additional information provided on each figure is the level of treatment both before and after the facility was upgraded. Treatment changes ranged from primary to secondary; poor secondary to upgraded secondary; secondary with phosphorus removal to AWT; secondary treatment to upgraded secondary with phosphorus removal; and secondary treatment to nitrification and filtration. Streams on which these treatment plants are located range in size from about summer low flow streams with flows of 2 cfs to streams with flows in excess of 1000 cfs.

Intensive data shown on Figure 3.1 to 3.4 and in Appendix C for post-improvement conditions were selected such that stream flows, temperatures, rainfall conditions, and point and nonpoint source loadings, were nearly equal to those which occurred during the pre-operative study. The purpose of selecting surveys with similar background conditions was to isolate as much as possible the changes in water quality caused by the POTW improvement.

There were case studies where before and after data were received and not included in the analysis because of variable background conditions. In one instance, a major tributary upstream of a dominant point source had a much larger flow in the post-operative data set. This larger flow along with the increased mass of BOD associated with the tributary did not allow the effects of increased treatment levels to be isolated from other effects, directly. In another stream, increased algal populations in the post-operative data set prevented isolation of point source effects.

Large changes in background conditions make it difficult, if not impossible, to separate the affects of treatment changes from other affects based only on water quality changes. Where this is the case, modeling can aid in problem

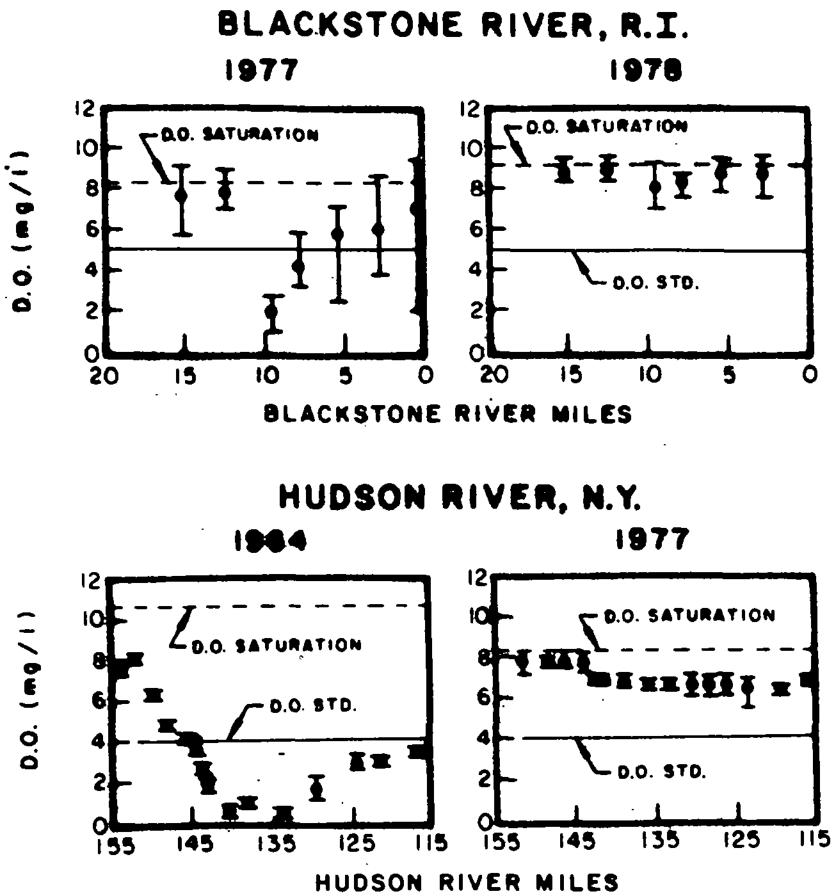
TABLE 3.1

WATER BODIES WITH BEFORE AND AFTER WATER QUALITY DATA

State	Water Body	Treatment Facility	Treatment Change	River[a] Flow/cfs	Data Availability W.Q.	Bio	Model
Massachusetts	Nashua River	Fitchburg Easterly	Secondary to Secondary & Nitrification	40	A	NA	A
Rhode Island	Blackstone River	Woonsocket	Primary to Upgraded Secondary	120	A	NA	NA
New York	Hudson River	Albany	Primary to Secondary	4000	A	NA	A
Maryland	Main Stem Patuxent	Laurel Parkway	Secondary to Secondary & Nitrification	30	A	NA	A
Maryland	Potomac Estuary	Blue Plains	Secondary & Primary Remedial to Secondary & Primary Remedial Nitrification	2000	A	NA	A
W. Virginia	Hurricane Creek	Hurricane	Poor Secondary to Upgraded Secondary	2	A	NA	A
Virginia	South River	DuPont (Industry)	Secondary to Secondary & Nitrification	80	A	NA	A
Michigan	Clinton River	Pontiac & Auburn	Secondary to Secondary & Primary Remedial	30	A	NA	A
Ohio	Ottawa River	Lima	Secondary to Secondary & Nitrification	60	A	A	NA
Wisconsin	Bridge Creek	Augusta	Secondary to Secondary & Nitrification	10	A	NA	NA
Wisconsin	Lemonweir	Tomah	Secondary to Secondary & Nitrification	5	A	NA	NA
Texas	Cibolo	Odo J. Reidal	Secondary to Upgraded Secondary	5	A	A	A
Missouri	Wilsons Creek	Springfield S.W.	Secondary to Secondary & Nitrification & Filters	40	A	A	A

[a]Approximate summer low flow including point source flows

PRIMARY TREATMENT TO UPGRADED SECONDARY



NOTES:

1. SEE TEXT OR APPENDIX C FOR DETAILS.
2. D.O. STANDARDS GENERALLY ARE NEVER LESS THAN BUT IN SOME CASES MAYBE DAILY AVERAGE.

Figure 3.1

Short Term Dissolved Oxygen Improvements

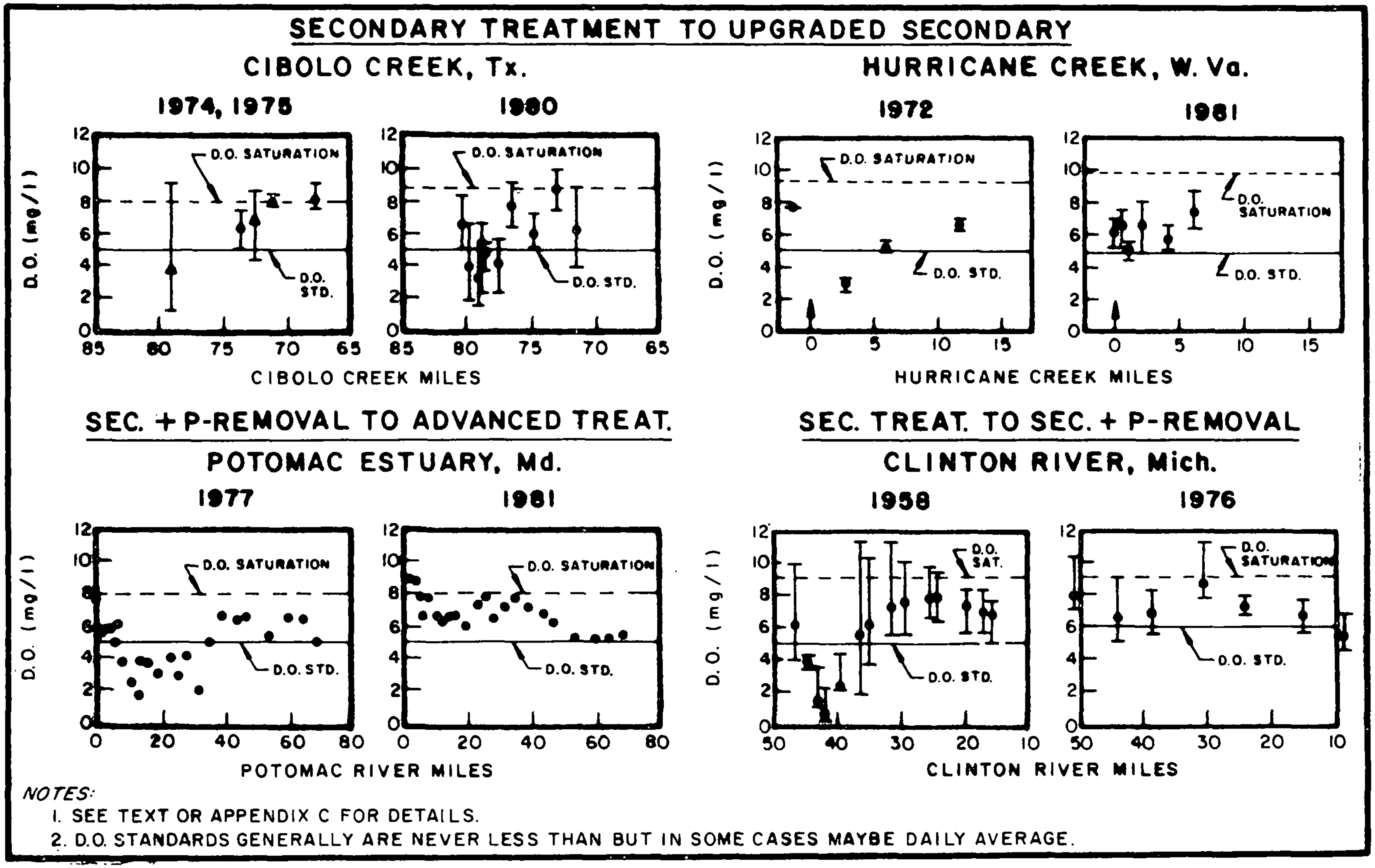
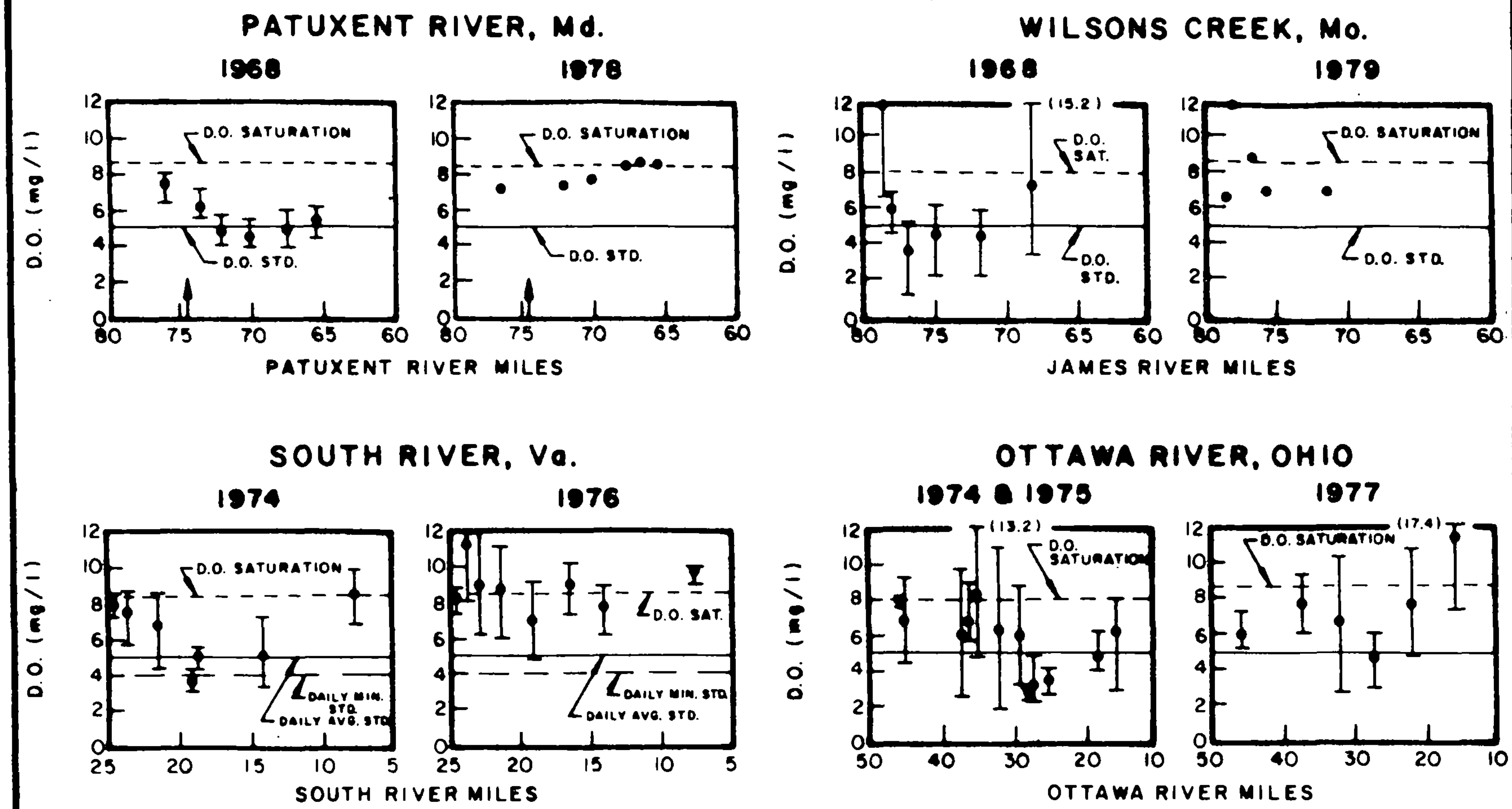


Figure 3.2

Short Term Dissolved Oxygen Improvements

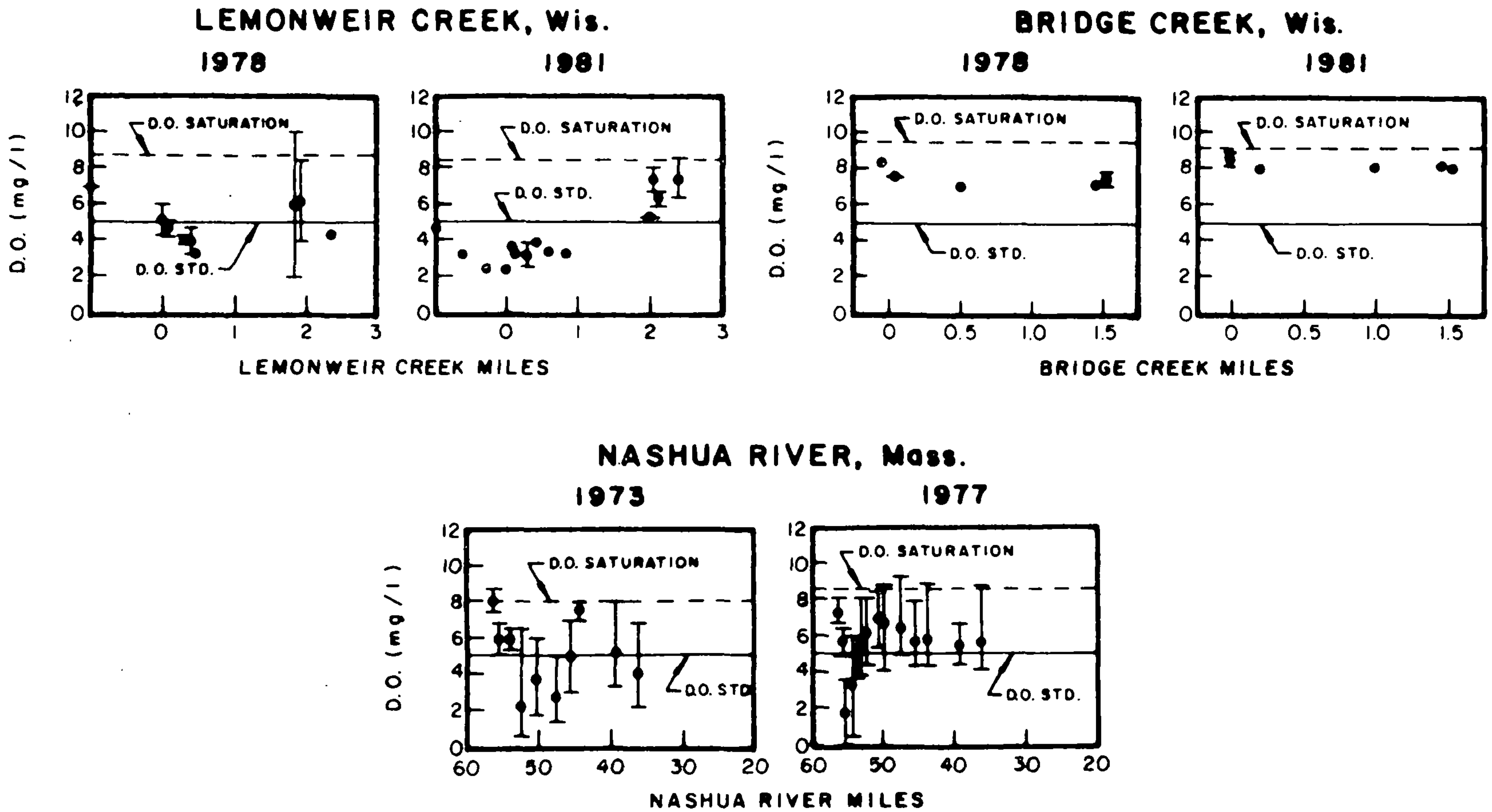


NOTES:

1. SEE TEXT OR APPENDIX C FOR DETAILS.
2. D.O. STANDARDS GENERALLY ARE NEVER LESS THAN BUT IN SOME CASES MAYBE DAILY AVERAGE.

Figure 3.3

Short Term Dissolved Oxygen Improvements (Secondary Treatment to Advanced Treatment)



NOTES:

1. SEE TEXT OR APPENDIX C FOR DETAILS.
2. D.O. STANDARDS GENERALLY ARE NEVER LESS THAN BUT IN SOME CASES MAYBE DAILY AVERAGE.

Figure 3.4

Short Term Dissolved Oxygen Improvements
(Secondary Treatment to Advanced Treatment)

evaluations. However, in this study, it was decided to assess improvements on observed water quality data and not use other tools such as models in the evaluations presented in this chapter.

Of the water bodies shown on Figures 3.1 to 3.4, all except Cibolo Creek, Ottawa River, and Lemonweir Creek show increases in dissolved oxygen concentrations after treatment levels were upgraded. Data presented on these figures has been further reduced as shown on Figure 3.5 to more quantitatively reflect dissolved oxygen changes. The upper panel on the figure presents the change in the absolute minimum dissolved oxygen concentration in the river while the lower panel presents the overall spatial average change in oxygen concentration.

Changes in treatment have increased short term minimum dissolved oxygen concentrations by an average of 2.6 mg/l, while daily and spatially averaged oxygen levels have increased by approximately 1.9 mg/l. In a few cases, either minimum or spatial average dissolved oxygen concentrations decreased by as much as 0.5 mg/l.

Those rivers which displayed the smallest short term changes in dissolved oxygen concentrations were rivers with:

a. large diurnal dissolved oxygen fluctuations - Cibolo, Ottawa, Nashua;
b. influences from upstream or other point sources - Lemonwier, Nashua, Ottawa;
c. elevated pre-operative dissolved oxygen concentrations - Bridge Creek, or;
d. minor reductions in POTW loadings - Cibolo Creek

Water bodies which displayed the largest changes in dissolved oxygen concentrations were rivers which:

a. had discharges located on them which were upgraded from primary to secondary treatment - Blackstone, Hudson
b. were dominated by a single major source of pollution which was upgraded from secondary to advanced treatment levels - Potomac, Clinton, Patuxent, South, Wilsons

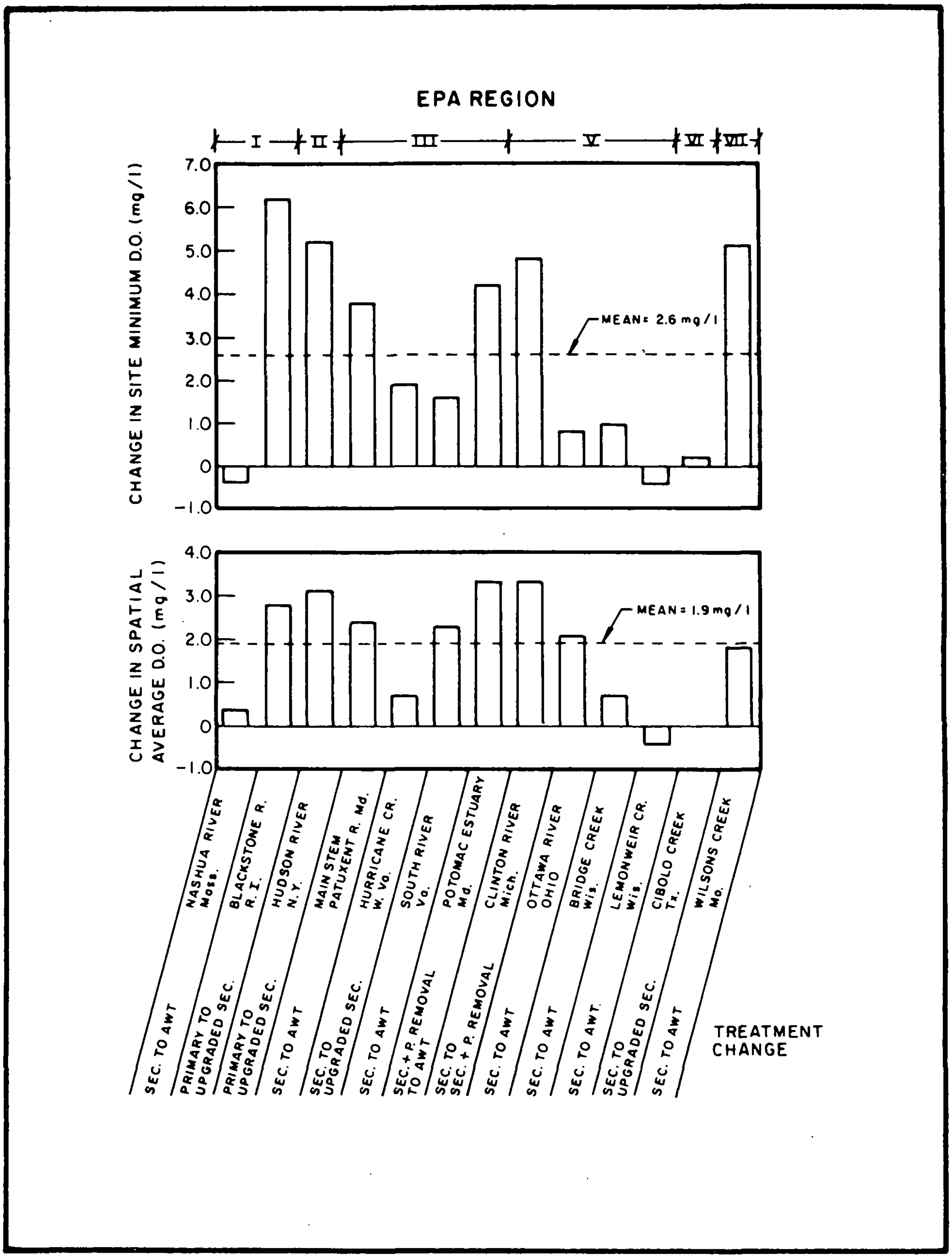


Figure 3.5

Summary of Short Term Dissolved Oxygen Improvements

Additional water chemistry changes are presented on Figure 3.6 for each of the 13 water bodies. Five-day BOD_5 concentration decreased as much as 29.0 mg/l in the Clinton River. Other water bodies such as the Nashua River, Patuxent River, Lemonweir Creek, and Wilsons Creek showed decreases in maximum BOD_5 concentration in excess of 10.0 to 15.0 mg/l. The Ottawa River and Bridge Creek exhibited increases in BOD_5 concentration.

Three of the data sets which exhibited large changes in dissolved oxygen were accompanied by large changes in BOD_5 (Patuxent, Clinton, Wilsons). However, the Nashua and Lemonweir which displayed small oxygen improvements did display a large reduction in instream BOD_5 concentrations. The Blackstone, Hudson, and Potomac Rivers also had large increases in oxygen levels, but had very small reductions in instream BOD_5. These data show that oxygen improvements are not always directly caused by reductions in instream BOD_5. The dissolved oxygen changes are sometimes caused by reductions in ammonia concentrations, ultimate CBOD concentrations or changes in other factors.

Additional improvements in instream water chemistry are also summarized on Figure 3.6 which presents changes in ammonia and un-ionized ammonia concentrations. In all cases where ammonia data are available, both instream ammonia and un-ionized ammonia concentrations were observed to decrease. Generally, decreases of about 5.0 mg/l were observed while un-ionized ammonia reductions were observed to be on the order of tenths of a mg/l. Two exceptions were the Ottawa River and Wilsons Creek, where maximum ammonia concentrations decreased by about 20.0 mg/l. In the Ottawa River, un-ionized ammonia also decreased by 7.5 mg/l.

Pre- and post-improvement dissolved oxygen and un-ionized ammonia concentrations are compared to water quality standards and criteria on Figure 3.7. As shown on this figure, 9 of the 13 rivers had post-operative dissolved oxygen concentrations which were above or very near the dissolved oxygen criteria. In four of the rivers, post-improvement oxygen concentrations were 2.0 mg/l or more below the dissolved oxygen standard. Before treatment was upgraded, dissolved oxygen standards were violated in all but one river.

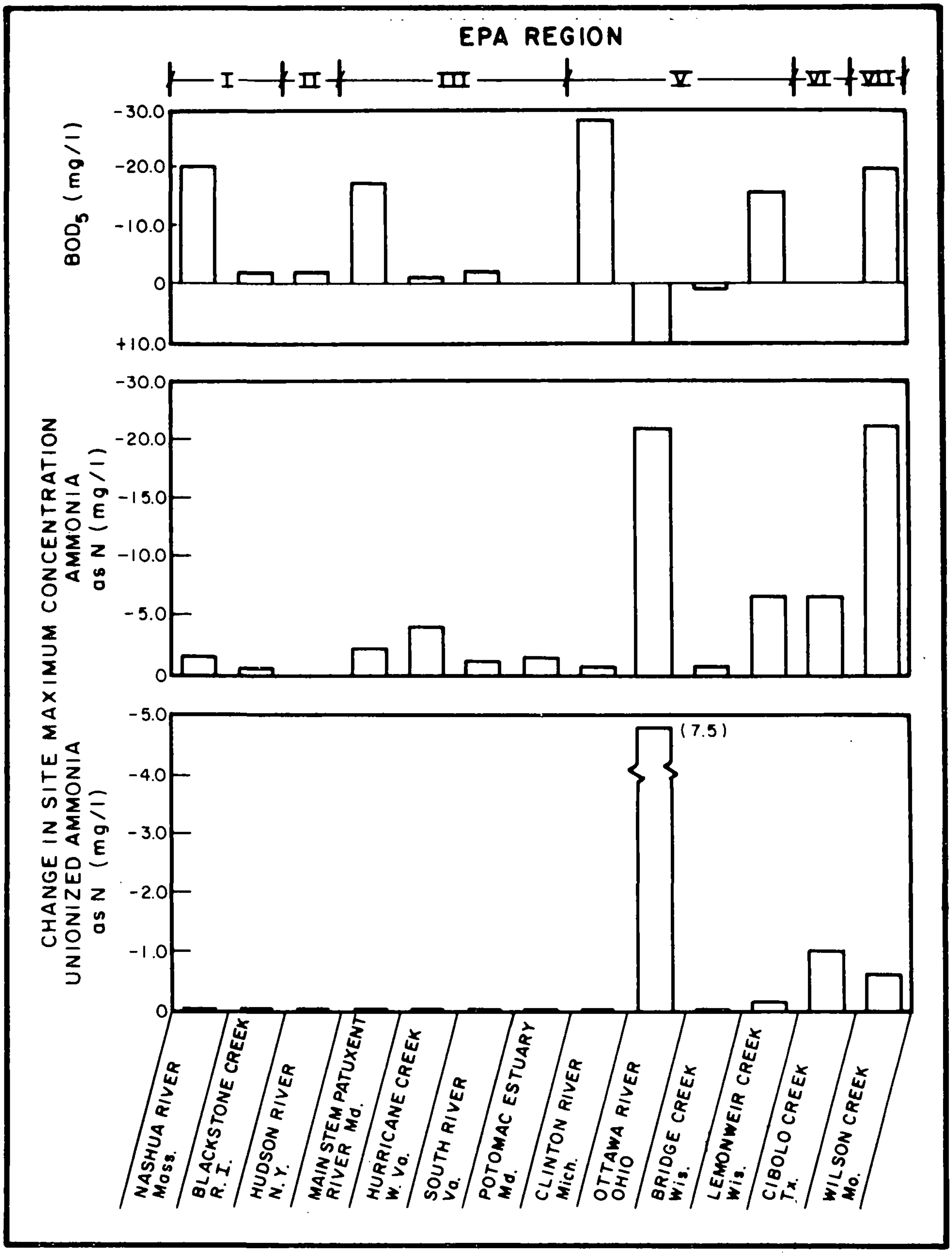


Figure 3.6

Summary of Short Term BOD_5, Ammonia and Unionized Ammonia Improvements

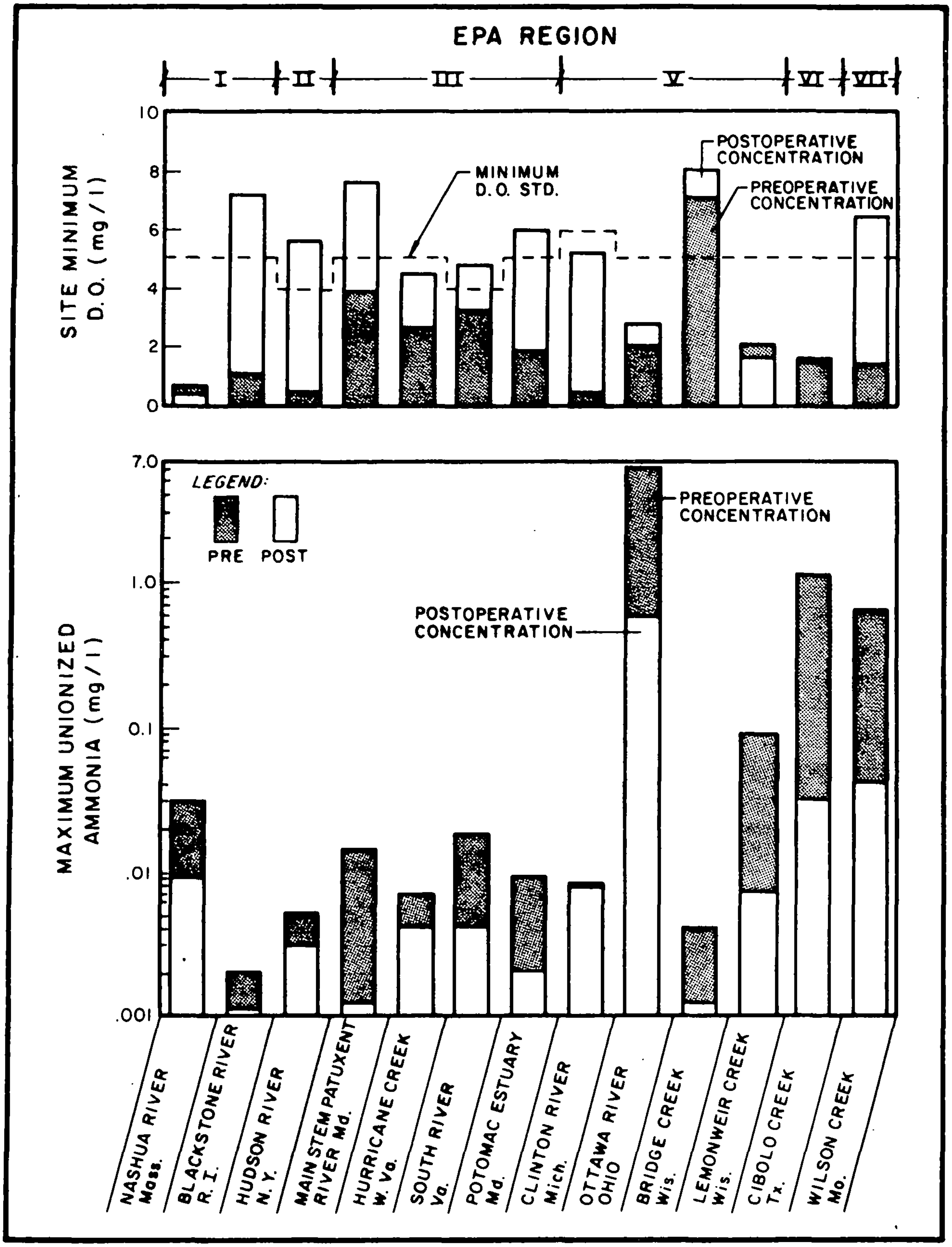


Figure 3.7

Comparison of Pre- and Post-Operative Data to Water Quality Criteria

Redbook un-ionized ammonia criteria were exceeded in 5 of the 13 rivers in the pre-operative studies. After treatment was upgraded, major un-ionized ammonia reductions occurred in those rivers where pre-improvement data exceeded suggested criteria. Of those rivers where un-ionized ammonia exceeded criteria, only the Ottawa River exceeds all criteria in the post-operative survey. Other than the POTWs, this river is impacted by two industries which discharge high effluent concentrations of ammonia-N. Even though nitrification has been installed at the Lima POTW, nitrification at the two industries appears to be necessary to further reduce ammonia and un-ionized ammonia concentrations.

Based on the pre- and post-improvement intensive survey data, short term improvements in water chemistry occurred for each level of POTW upgrading. With respect to dissolved oxygen levels, upgrading of POTWs has resulted in approximately a 2.0 mg/l increase across the 13 water bodies. In most of these water bodies, this increase in dissolved oxygen was enough to raise the minimum concentration to a level very near or greater than the appropriate dissolved oxygen standard. Where oxygen levels were not substantially changed by treatment, other dominant point or nonpoint source loads which existed remained constant or increased in mass pollutant discharge rates. Biochemical oxygen demand, ammonia and un-ionized ammonia reductions also accompanied the upgrading of treatment processes.

Where the largest dissolved oxygen improvements were noted to ocur, installation of improved treatment systems decreased river loadings of both CBOD and ammonia. For the Blackstone River, Hudson River, Patuxent River, Potomac River, Clinton River, and Wilsons Creek, minimum river dissolved oxygen concentrations were observed to increase by 3.0 mg/l or more. In these systems, point source BOD_5 loadings were decreased by between 55 and 94 percent. Ammonia mass discharges from point sources were decreased by between 50 and 90 percent.

In the other water bodies where lesser dissolved oxygen improvements were observed, a number of factors were responsible for the small changes in dissolved oxygen concentrations. In the Nashua, post-improvement river flows were near 7Q10, while pre-improvement flows were about five times 7Q10 and BOD_5 point inputs to the river only decreased by some 29 percent. In Hurricane Creek, BOD_5 point loads were reduced by about 90 percent, while post-operational river flow was again, near the 7Q10 which was less than the pre-improvement river flow. Other reasons noted for smaller improvements are that the point discharge flow receives a large stream dilution upon discharge (Bridge Creek) and/or nonpoint sources of pollution are a major influence on the oxygen balance of the river (Lemonweir).

Variability of instream oxygen concentrations are evaluated for pre-improvement and post-improvement settings on Figure 3.8. The ordinate on this figure is the difference between the observed daily mean dissolved oxygen at any given location and the minimum dissolved oxygen measured on that day at the same location. The abscissa on Figure 3.8 is the mean dissolved oxygen. The observed variation in dissolved oxygen (ordinate) is caused by many factors including photosynthetic activity and variations in flow, point and nonpoint loadings, and temperature.

The mean dissolved oxygen minus the minimum dissolved oxygen as shown on Figure 3.8 is randomly distributed across all mean dissolved oxygen concentrations. Further, the measure of variation changes very little with treatment. Pre-improvement stream dissolved oxygen variations average about 1.3 mg/l while post-improvement variations average about 1.1 mg/l. With the given standard deviations, each of which is near 1.0 mg/l, the pre- and post-treatment variations are not significantly different.

This information may be useful to analysts performing wasteload allocations. In many cases, the analyst utilizes a mathematical model which calculates steady state daily average dissolved oxygen concentrations. Standards, however, are often written as "never less than." Unless there is an actual data base of dissolved oxygen variability, the analyst has no way of relating the model output to the "never less than" standard. In such instances, an oxygen variation equal to 1.0 mg/l (plus and minus 1.0 mg/l) can be subtracted from the

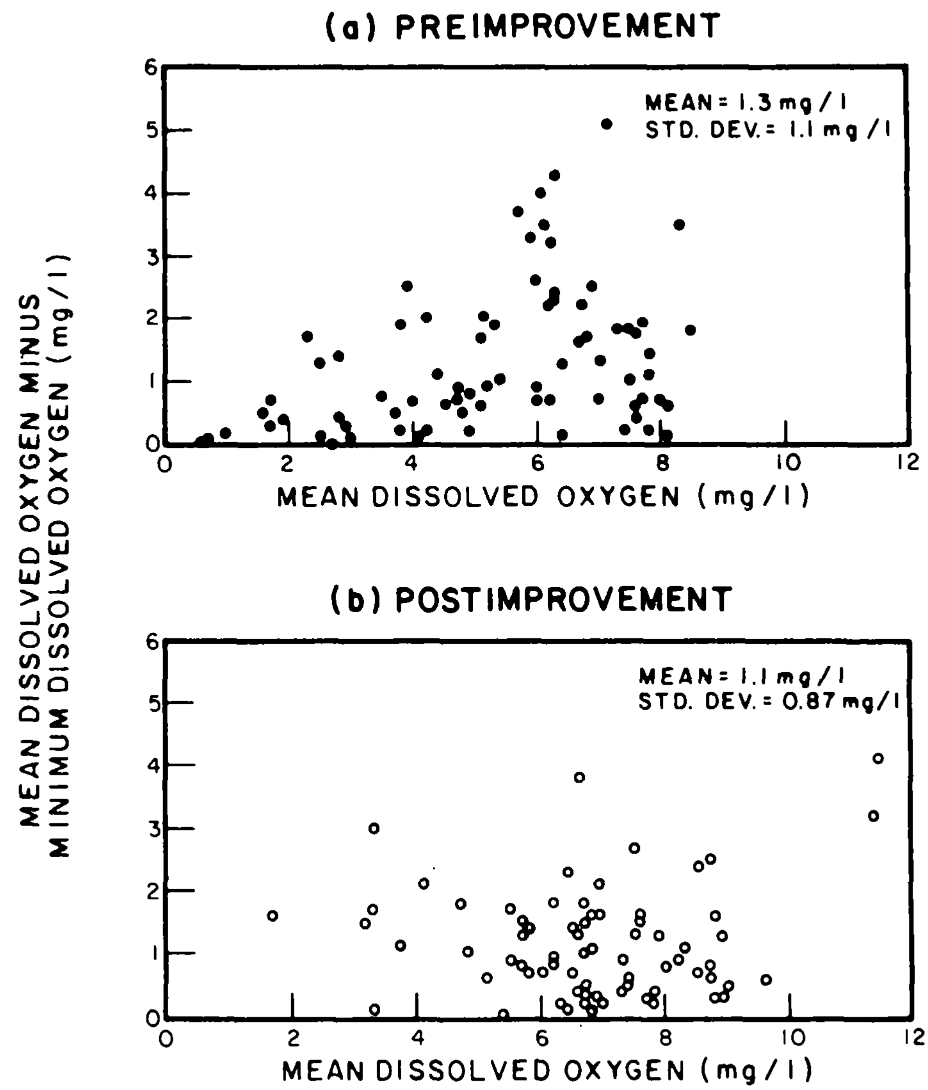


Figure 3.8

Summary of Site Dissolved Oxygen Variations for Thirteen Water Bodies

daily average model calculations to provide an estimate of the "never less than" dissolved oxygen level. Although, this suggestion is being made to deal with "never less than" standards, the suggested variation is highly variable. If this approach is employed, the analyst should use the site specific data wherever possible. Consideration should also be given by analysts and administrators to a statistical standard such as "greater than 90 percent of the time," as opposed to a "never less than" standard. In addition to being more realistic, this type standard can be approached more accurately in technical evaluations.

3.2 Seasonal Water Chemistry

Additional water chemistry data which are available to assess changes in water quality in response to point source treatment changes are from routine water quality monitoring stations. These data are collected at stations located at fixed points on rivers. The stations are sampled on a regular basis (weekly or monthly) by a variety of agencies including the United States Geological Survey (USGS), the USEPA and/or many of the states. Data from these stations were retrieved during this study from the STORET[4] data base. These data are presented in Appendix C as time history plots for many rivers.

June, July, August and September dissolved oxygen and ammonia concentrations have been extracted from the data base and are presented on Figures 3.9 and 3.10 for Wilsons Creek, Clinton River, South River and Blackstone River. Summer and annual average statistical properties developed at each of these stations are presented in Table 3.2. The data indicate that dissolved oxygen has been increased by about 1.6 mg/l on a year round basis and about 2.6 mg/l on a summer average basis. These findings are consistent with the short term improvements based on the intensive survey data presented in Section 3.1.

Table 3.3 presents information on the frequency of dissolved oxygen standard violations for the pre- and post-operative routine monitoring sampling data.

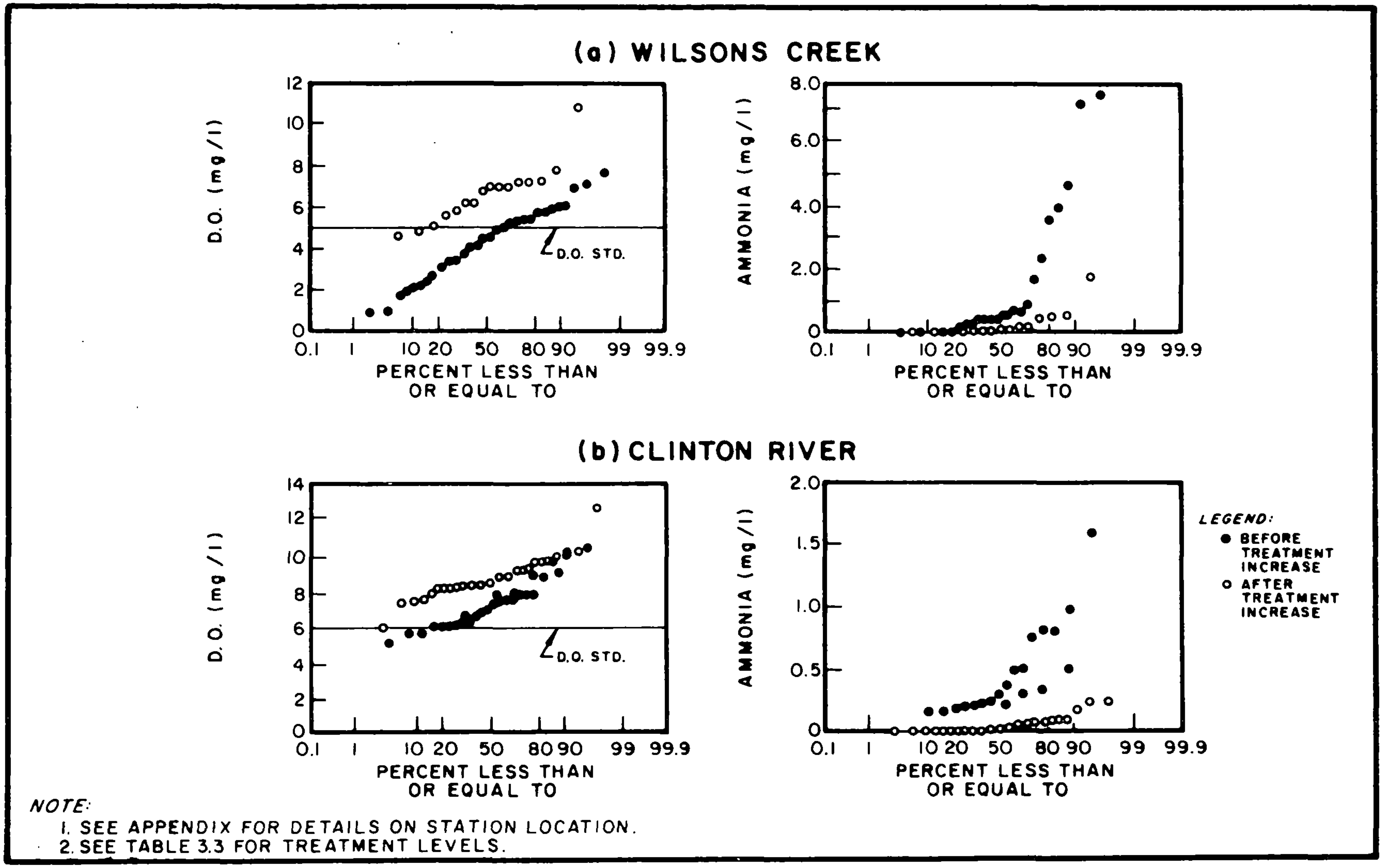


Figure 3.9

Probability Distribution of Summer Dissolved Oxygen and Ammonia Concentrations at Fixed Location Monitoring Stations

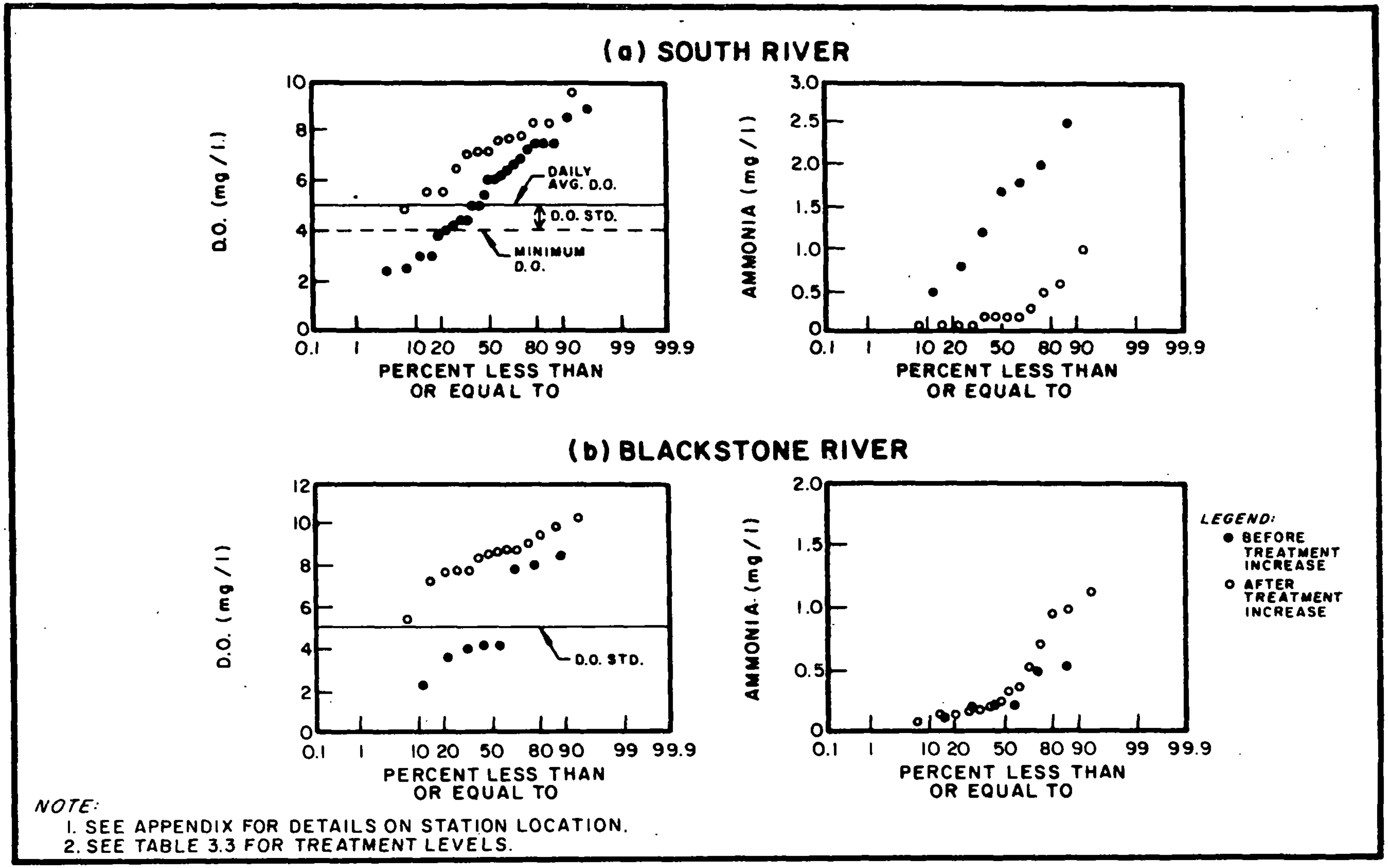


Figure 3.10

Probability Distribution of Summer Dissolved Oxygen and Ammonia Concentrations at Fixed Location Monitoring Stations

TABLE 3.2

STATISTICAL SUMMARY WATER OF CHEMISTRY IMPROVEMENTS

Water Body	Annual Changes[a,b]		Summer Changes[a,b]			
	Dissolved Oxygen Before	Dissolved Oxygen After	Dissolved Oxygen Before	Dissolved Oxygen After	NH_3 Before	NH_3 After
Wilsons Creek	6.8	9.2	4.7 (1.6)	7.0 (1.5)	1.4 (2.1)	0.25 (0.44)
Clinton River[c]	8.6	10.6	7.2 (1.5)	8.5 (1.1)	0.47 (0.43)	0.06 (0.06)
Patuxent River	-	-	3.7 (-)	7.6 (-)	-	-
Blackstone River[d]	8.9	10.8	5.3 (2.4)	8.3 (1.2)	0.29 (0.17)	0.41 (0.33)
South River	7.9	8.7	5.6 (2.8)	7.0 (2.1)	1.50 (0.65)	0.30 (0.27)
Lemonweir River	7.2	7.9	5.0 (4.4)	- (2.0)	-	-

[a]All values with units of mg/l
[b]Number in ( ) is standard deviation
[c]Before 1 POTW @ P-Removal, 1 POTW @ secondary treatment: After both POTWs @ secondary + P-Removal + nitrification
[d]Primary to secondary treatment

TABLE 3.3

SUMMARY OF MONITORING DATA STATISTICAL CHANGES

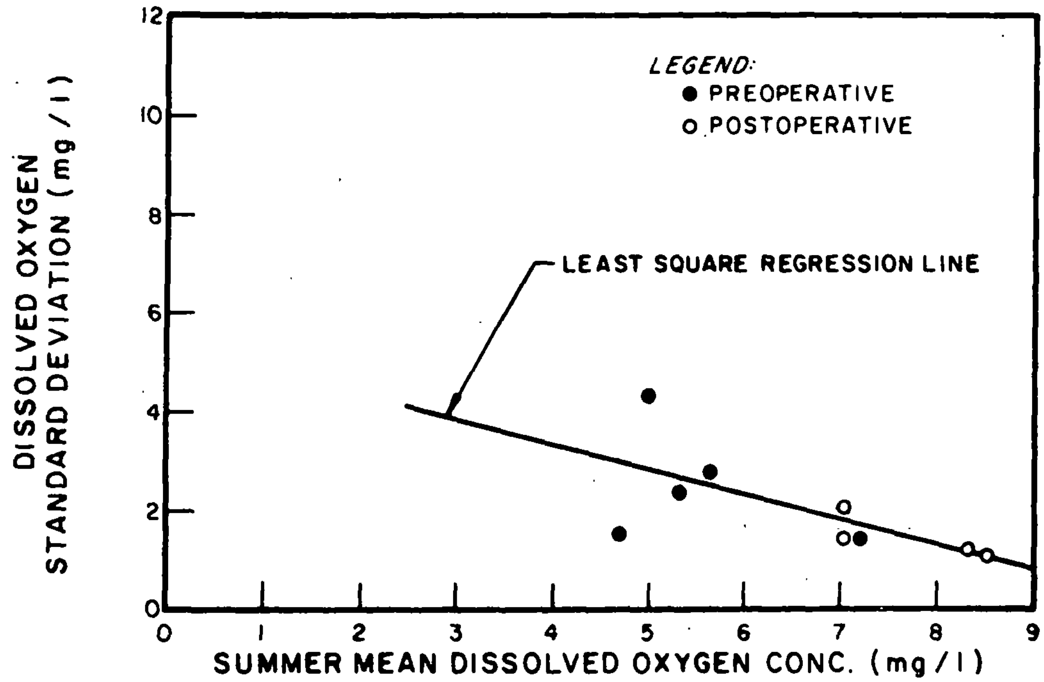
River	Treatment Change	Approximate Percent of Data Less than Dissolved Oxygen Standard	
		Pre-Improvement	Post-Operative
Wilsons	Secondary to secondary & nitrification filters	60	15
Clinton	One POTW secondary & one POTW secondary & P-removal to both at secondary & primary removal and nitrification	20	3
South	Industry at secondary to industry industry at nitrification	25	2
Blackstone	Primary to upgraded secondary	60	1

Before construction upgrades for the specific projects dissolved oxygen standards were violated between 20 and 60 percent of the time. After the projects came on line, violations occurred between 1 and 15 percent of the time. In the case of Wilsons Creek, long term improvements may be less optimistic since post-improvement POTW flows are only at about 80 percent of design flow. However, observed improvements may accurately represent long term improvements for the Clinton, South and Blackstone Rivers since post-operational POTW effluent flows approximate design flows.

Pre- and post-improvement instream ammonia concentrations are also summarized on Figures 3.10 and 3.11 and in Table 3.2 for summer periods. On Wilsons Creek, Clinton River and the South River, nitrification facilities were installed at the major point sources. Monitoring data indicate this results in a mean ammonia reduction of approximately 0.9 mg/l. The ammonia standard deviation for these rivers has also been reduced from 1.1 to 0.25 mg/l over the three sampling sites. Treatment changes also have reduced the magnitude of extreme events. For example, in Wilsons Creek before nitrification was installed, an ammonia concentration of 1.0 mg/l was exceeded about 30 percent of the time. After treatment was upgraded, an ammonia concentration of 1.0 mg/l was exceeded less than 10 percent of the time. Similar results are observed in the other two rivers. This trend, however, is not true for the Blackstone River where the change in treatment from primary to secondary has not influenced the instream ammonia probability distribitions.

Both the ammonia and dissolved oxygen data presented in Table 3.2 are also presented on Figure 3.11 as a regression analysis of standard deviation against the mean data. Dissolved oxygen data indicate that the standard deviation decreases as the mean approaches the dissolved oxygen saturation concentration (8.0 to 9.0 mg/l during summer). The ammonia-N standard deviation data show a decreasing trend with decreasing mean ammonia concentration.

Short term oxygen improvements observed from routine monitoring stations indicate summer and annual average increases in dissolved oxygen in the range of



NOTE:
SEE APPENDIX C TIME HISTORY ANALYSIS FIGURES AND FOR STATION LOCATIONS AND ORIGINAL DATA.

Figure 3.11

Summer Standard Deviation of Dissolved Oxygen and Ammonia Concentrations

2.0 mg/l. These observations are in agreement with site minimum and spatial average dissolved oxygen improvements observed from intensive survey data (Section 3.1). For three of the water bodies, long term (design flow) dissolved oxygen improvements may equal short term improvements. Improvements in waste treatment, specifically upgrading to AWT has also decreased the frequency at which standards were violated.

3.3 Biology

Biological indicators such as benthic macroinvertebrate and fish populations can be used to assess the general health of a water body. These organisms tend to reflect the overall water chemistry in rivers and streams. To a certain extent, they are also good indicators of the history of the water body over the preceding weeks and months.

During the data collection phase of this post-improvement assessment, biology data were requested from contact agencies as well as the water chemistry data previously discussed. A substantial amount of macroinvertebrate data were forwarded to HydroQual in response to the requests. These data were reviewed along with other information to develop a complete picture of the water body through the period of facility upgrading.

Two of the thirteen before and after data sets collected in this study also contained detailed biology data. Data from Wilsons Creek and the Ottawa River are presented on Figure 3.12.

Wilsons Creek macroinvertebrate data from 1964 to 1965 represent pre-improvement conditions and data from 1980 represent post-improvement conditions. In this single point load river, the Springfield Southwest POTW was operating as a secondary treatment facility in 1964 to 1965 and was operating with nitrification and filtration in 1980. The number of taxa downstream of the POTW was less than 5 in 1964 to 1965 while after upgrading to AWT the number of taxa were between 10 and 20. Downstream of river mile 71.5 where Wilsons Creek flows into

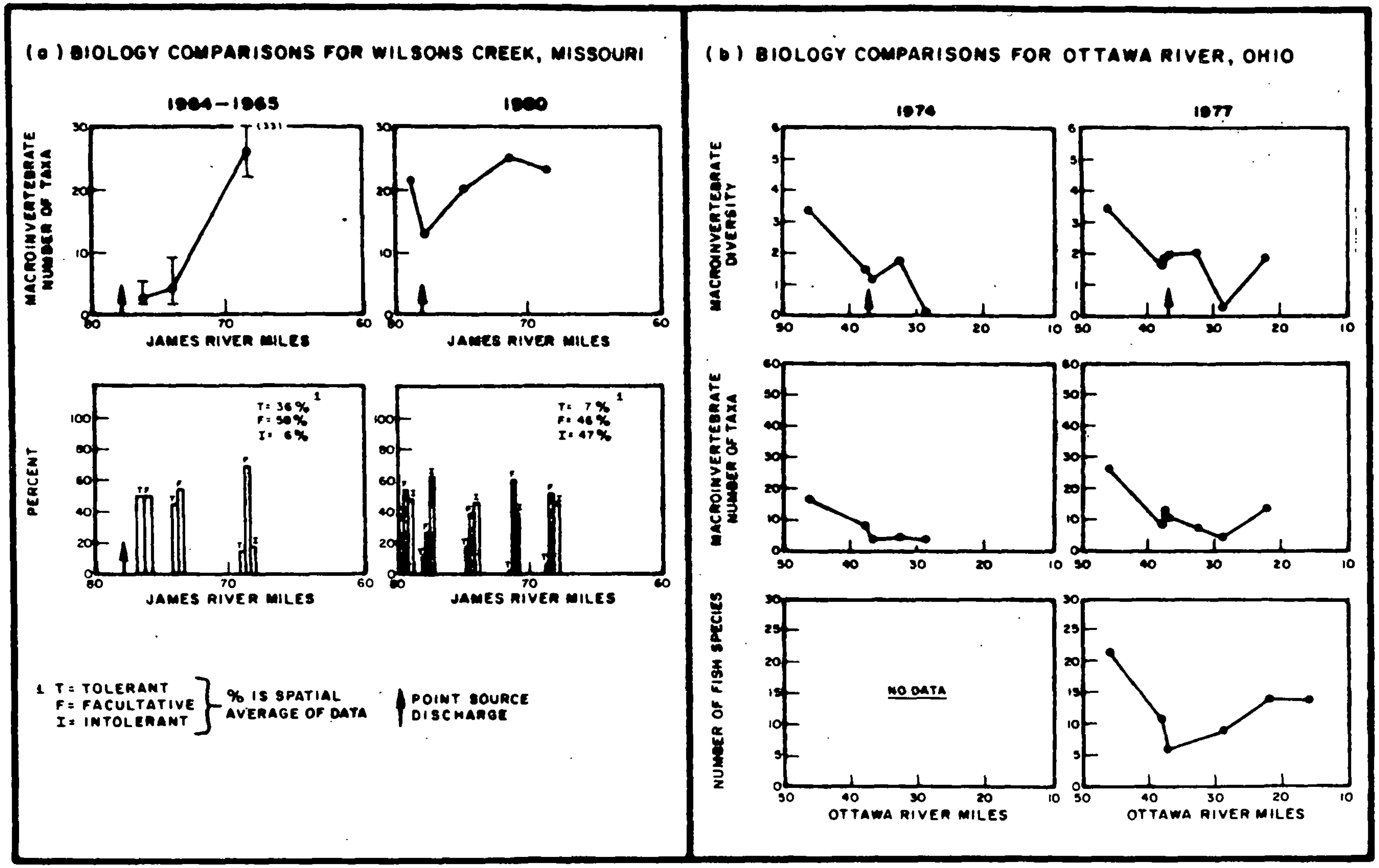


Figure 3.12

Preoperational and Postoperational Biology Data

the larger James River, macroinvertebrate data are relatively the same at both treatment levels.

Water quality before and after AWT was imposed, is also evaluated based on the distribution of the macroinvertebrates between pollution tolerant, facultative, and pollution intolerant species in the lower graphs on Figure 3.12. The stream in 1964 to 1965 (secondary treatment) was dominated by pollution tolerant and facultative species of benthic organisms when 94 percent of the organisms were from these two groups. In 1980, there was an increase in the number of pollution intolerant species at every location downstream of the POTW. The overall improvement was from 94 percent tolerant and facultative and 6 percent intolerant species in 1964 to 1965 to 53 percent tolerant and facultative and 47 percent intolerant species in 1980. The only major change in the river during this period was upgrading the Springfield Southwest POTW from secondary to nitrification and filtration and the increased POTW effluent flow to the river.

Biology data for the Ottawa River is presented on Figure 3.12(b). This river receives waste discharges from the city of Lima POTW and two industrial discharges. Between 1974 and 1977, a nitrification process installed at the Lima POTW improved dissolved oxygen, ammonia and un-ionized ammonia levels in the river. After treatment, minimum oxygen concentrations and maximum un-ionized ammonia concentrations were still in violation of water quality criteria (Figure 3.7).

Macroinvertebrate data presented on Figure 3.13(b) show the species diversity as well as the number of taxa to be about the same both before and after nitrification was installed at the Lima POTW. No significant improvement in macroinvertebrate organism distributions indicates that upgrading treatment at the Lima POTW was not adequate to improve river chemical and biological quality. This lack of improvement in biological quality is presumed to be caused in part by two other significant pollutant discharges in the study area which did not modify treatment during this time period.

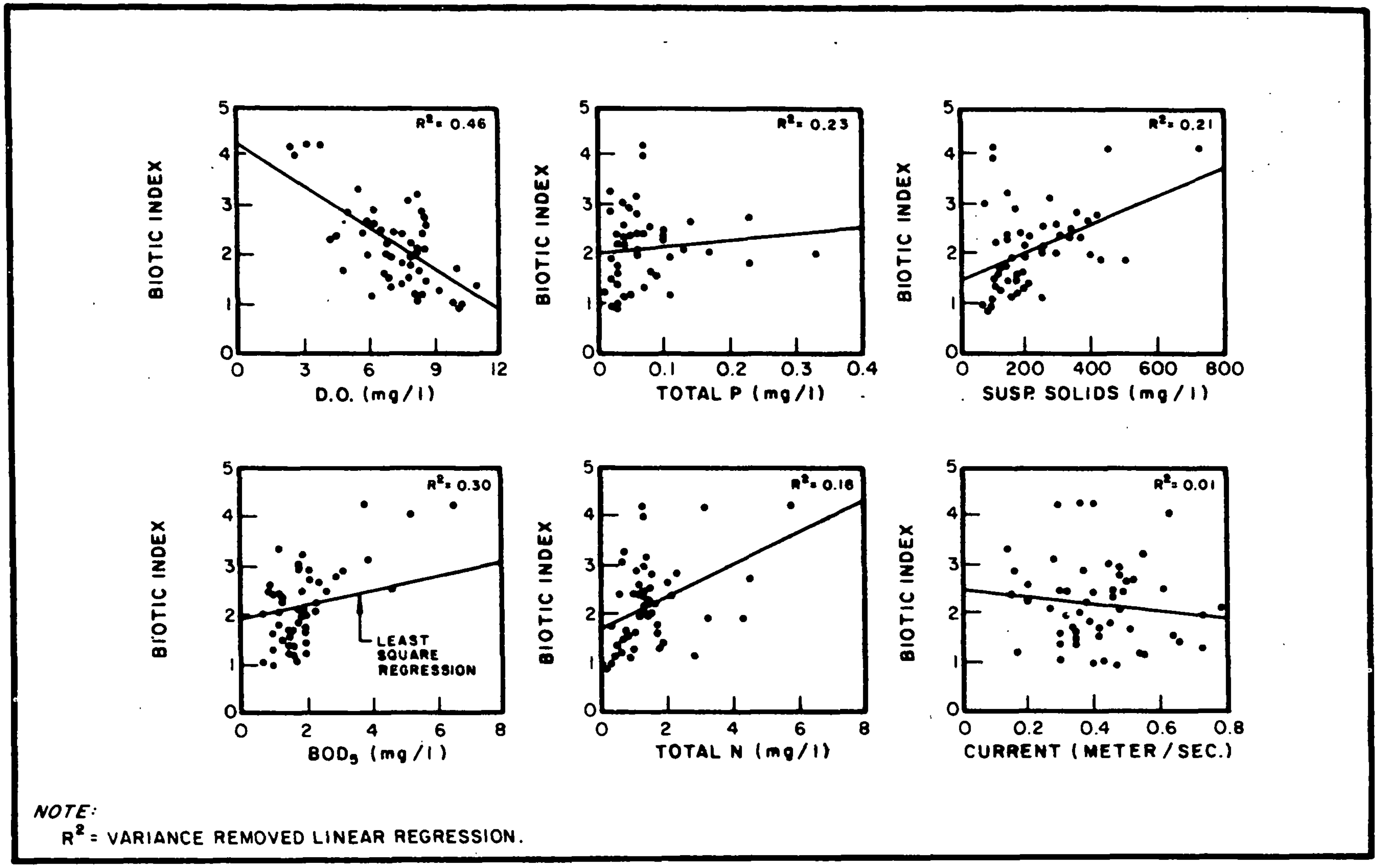


Figure 3.13

Review of Macroinvertebrate Data from Fifty-Three Wisconsin Streams

Additional qualitative information was available in a few of the river basins (Clinton, Cibolo) discussed earlier as well as a few others not included in the 13 water bodies.

a. Clinton River: Between 1955 and 1972, secondary treatment was upgraded at one facility and a second activated sludge facility was constructed providing high quality treatment. A biological survey conducted in 1955 between Pontiac and Rochester indicated that benthic macroinvertebrate communities were grossly degraded for the entire 30 mile reach. A macroinvertebrate inventory conducted in 1972 shows the community structure to be completely recovered from pollution influence at a point some nine miles downstream from the city of Pontiac. Fish count studies conducted in 1973 indicated that although the physical environment for fish was excellent, there was a general lack of fish diversity and fish counts showed a very stressed fish population. The river was also not being stocked in 1973. Although, quantitative information is not available, a Department of Natural Resources biologist stated that in 1982 the Clinton River was being stocked with game fish. Between 1973 and 1982, sewage was diverted to a single facility providing nitrification, phosphorus removal, and filtration.

b. Cibolo Creek: Water chemistry data showed only minor improvements to stream dissolved oxygen, BOD, and nitrogen concentrations after construction of an upgraded secondary treatment facility. Benthic macroinvertibrate data collected before the plant was constructed showed the number of taxa to average 12 organisms; the diversity index to average 1.37; and the number of individuals per square foot to average about 1300 for a seven mile reach downstream of the POTW. In this same reach after the new treatment plant was constructed, the number of taxa increased to 17, the diversity was about 1.45, and the number of organisms per square foot decreased to about 700. Therefore, biological indicators tended to be consistent with water chemistry data which showed no major changes in the stream upon construction of the new facility.

c. Spring Brook, Wisconsin: This river, which was not included in the 13 water bodies evaluated in detail, contained chemical and biological data collected both before and after upgrading the Antigo POTW from trickling filters to activated sludge secondary with nitrification. October 1978 water chemistry data collected before the treatment facility was upgraded showed depressed dissolved oxygen levels (minimum 2.7 mg/l) and macroinvertebrate biotic index values of 4.32 (very poor), 4.48 (very poor) and 3.63 (poor) downstream of the POTW. October 1981 data were collected when the treatment facility was discharging 19.0 mg/l of BOD_5, compared to 140.0 mg/l in 1978 and 3.0 mg/l of ammonia, compared to 26.0 mg/l in 1978. These water quality data showed a minimum river dissolved oxygen of 7.9 mg/l and macroinvertebrate indicies of 4.04 (very poor), 3.42 (poor) and 2.04 (fair) downstream of the POTW.

d. North Branch Pigeon River, Wisconsin: This river was not included in the 13 water bodies evaluated in detail. In 1978, the Marion POTW was treating municipal wastes to a level of secondary treatment (effluent BOD_5 of 21.0 mg/l). Downstream macroinvertebrate biotic index values at that time were 3.0 (poor), 3.15 (poor) and 3.8 (very poor). After being upgraded to secondary treatment with inplant nitrification, downstream biotic index values where greatly improved to 2.10 (good), 2.24 (good), and 2.05 (good).

Although these data were available to assess changes in biology, both before and after treatment improvements, the utility of biology data is improved when detailed physical and water chemistry data are available for similar time periods.

Additional sets of biology data were not available to assess changes in treatment levels, however, data were available to qualitatively demonstrate the relationship between water chemistry and benthic macroinvertebrate indices. These data derived from a recent study of 53 Wisconsin streams[5] are presented on Figure 3.13 as regression of biotic index against river dissolved oxygen, total phosphorus, suspended solids, BOD_5, total nitrogen, and stream velocity.

On this figure, the biotic index (ordinate) is a summation of the number of individual species times a quality index value divided by the total number of organisms in the sample. The abscissa on the figure shows the independent variable which is dissolved oxygen concentration. Table 3.4 is presented by the author to show general relationship between biotic index and water quality.

TABLE 3.4

WATER QUALITY INDEX FOR BIOTIC INDEX VALUES[5]

Index	Water Quality	State of Stream
<1.75	Excellent	No organic pollution
1.75 - 2.25	Very good	Possible slight pollution
2.26 - 2.75	Good	Some pollution
2.76 - 3.50	Fair	Significant pollution
3.51 - 4.25	Poor	Very significant pollution
4.26 - 5.00	Very Poor	Severe pollution

The regressions show no strong correlations between biotic index and BOD_5, nitrogen, phosphorous, suspended solids, and velocity. Correlation coefficients (r^2) values were less than .30 for these parameters. However, there was a fairly good correlation (r^2 of .46) between biotic index and dissolved oxygen. The information suggests that reductions in stream pollution and corresponding increases in dissolved oxygen does reduce the biotic index. The reduced biotic index represents the presence of less pollution tolerant macroinvertebrates which in turn produces a more diverse population of macroinvertebrates.

Macroinvertebrates are a commonly used indicator of the biological health of a waterbody and are a valuable method of quantifying and qualifying biological changes in water quality that occur from changes in water chemistry. Macroinvertebrates are generally preferred over fish in biological surveys because they are easier to collect and evaluate. The underlying assumption in the use of macroinvertebrates as a biological indicator is that the environmental conditions necessary for a diverse macroinvertebrate population are also the conditions that can support a healthy and diverse fish population.

These data are presented in order to evaluate relationships which may exist between biota and stream parameters. In any given stream, these relationships may change, or may be limited by physical constraints such as bottom characteristics. Further, these data which are collected across a number of streams and across a range of temperatures of between $0^{o}C$ and $30.5^{o}C$, may not represent conditions in any single stream. Where similar data are to be employed in developing site specific criteria, the analysts can develop similar type analyses in that specific stream.

Only four cases contained enough data to assess biological changes due to additional treatment. As shown on Figure 3.12 Wilsons Creek, which did have a signficant change in water quality, also had a shift toward pollution sensitive macroinvertebrates after AWT (secondary, nitrification, and filters) was installed at the Springfield Southwest POTW. Similarly, in the Ottawa River where water chemistry changes are less significant, virtually no change in the macroinvertebrate community was observed after upgrading to AWT (secondary and nitrification) was installed at the Ottawa POTW. Qualitative information available for the Nashua River and the South River showed similar results. In the Nashua where water chemistry changes were minor, there was no shift in the biological community, while a shift to pollution sensitive macroinvertebrates occurred in the South River after major improvement in water chemistry. Based on this limited data there appears to be a correlation between the amounts of improvement in water chemistry and the diversity of the macroinvertebrate community, as one might expect.

Although these benthic and fish organisms are dependent on water chemistry, they are also dependent on the physical habitat or physical characteristics of the waterbody. Because of this dependence and the inability of additional treatment to change these characteristics, an improvement in water chemistry will not always be accompanied by a change in the benthic and fish communities. Therefore, consideration of physical as well as the chemical and biological factors must be considered when assessing the water quality benefits from a treatment project and the attainability of fish related beneficial uses for a given waterbody.

3.4 Physical Habitat

Physical habitat factors include water temperature, depth, stream velocity, stream bed substate, stream bank vegetation, and stream bank cover (shading). Treatment can change only one element of the physical habitat of waterbody; the bed substrate. In rivers where discharges are obtaining poor solids removal or where there is insufficient velocity in the stream to suspend solid material, sludge beds may build up on the stream bottom. Sludge beds are generally not acceptable to most game fish. Data, however, were not available from the information collected for these case studies to assess the significance of sludge beds. All other physical habitat parameters are functions of the waterbody itself and cannot be changed by increasing treatment levels.

While water chemistry improved in all 13 cases, habitat restrictions may have restricted the degree of the water quality improvements. Unfortunately, this type of subjective data concerning the suitability of the aquatic habitat to support a certain fish population was not available. Physical habitat is an important factor to consider in predicting the improvements that will result from a treatment project, and therefore should be evaluated in addition to physical/chemical information as part of the wasteload allocation or the determination of use attainability.

3.5 Recreation

The last and most difficult step in the pre- and post-improvement review is the assessment of recreation changes which have resulted from the project. Data were not available to quantitatively assess recreational changes. Angler (fishing) day data were collected by New York State through the 1970s but were not available for release in the time frame of this project. The only other data which give insight to recreational changes are summarized below.

a. Hudson River: Since the upgrade from primary to secondary treatment, two new marinas and two new riverside parks have been constructed in the study area.

b. Nashua River: Canoeing has become popular in the basin. A 300 foot wide recreational park has been established along 40 miles of the river.

c. Wilsons Creek: An historic battlefield park has been established on the river banks. Pollution sensitive fish species now swim in the creek just downstream from the effluent discharge pipe. Angler activity has noticeably increased since project completion. However, no quantitative data were available to definitively document these changes.

d. Potomac Estuary: Overall, recreational improvements have been noted through the 1970s which were a period of clean-up through installation of advanced treatment and upgrading secondary treatment at many POTWs. There has been an increase in the number of large mouth bass caught near the Capital District in recent years.(8) There is also a trend of increasing commercial fish landings through the 1970s.(9)

In general, these factors indicate for the study areas evaluated, the stream has become a more important recreational area since treatment was upgraded. Water quality has improved significantly in three of these water bodies, while in the Nashua, quality improvements have not totally been achieved but are anticipated to occur in the near future.

SECTION 4.0

WATER QUALITY MATHEMATICAL MODEL EVALUATIONS

Mathematical water quality models have evolved from the early 1900s to become tools used by many present day water quality planners to make wasteload allocation decisions. Models have grown from simple analytical equations to multi-segmented computer based models requiring large amounts of memory on high speed computers. In addition to individual simplified procedures such as the "26 pound Rule"[10] or "dilution ratio calculations,"[11] models are generally the only technical tools available for predicting treatment requirements necessary to protect dissolved oxygen resources under future loading conditions.

Rigorous evaluations have not been performed to date to show the accuracy of calibrated models after a treatment facility has been upgraded. The compilation of before and after data discussed earlier provides the information necessary to "truly" verify the accuracy of models to predict dissolved oxygen changes in response to POTW improvements. This section of the report presents an evaluation of cases where treatment changes were instituted based on a water quality model and where data were available as discussed in Section 3.0 to evaluate the ability of the models to accurately reproduce after field sampling data.

4.1 Model Calibration and Low Flow Water Quality Projections

The 13 water bodies discussed in Section 3.0 had sufficient data to perform pre- and post-improvement water chemistry evaluations. On all but three of these water bodies, planners utilized water quality models to develop wasteload allocations. A model was not utilized on the Blackstone River since at the time of construction, federal law mandated that all POTWs discharging to inland waters treat to a minimum level of secondary treatment. The "26 pound rule," which assumes Wisconsin streams can assimilate 26 pounds of BOD_5 per cubic foot per second of stream flow, and un-ionized ammonia criteria violations were the basis of the inplant nitrification for the POTWs discharging to Bridge Creek and Lemonweir Creek.

On the remaining 10 water bodies, mathematical models were employed to develop wasteload allocations and total maximum daily loads. Six of these models were obtained for review during this study. The other four models were not available for analysis.

Modeling analyses were, therefore, available for the main stem Patuxent River, Wilsons Creek, Hurricane Creek, Cibolo Creek, Clinton River, and the Hudson River. For Hurricane Creek, Cibolo River, and Clinton River, the models discussed in this and subsequent sections of this chapter were selected, because they were calibrated at stream flows and temperatures similar to conditions which existed during post-operational surveys. Other and more up to date models[14,15] either exist or will be developed for each of these water bodies. For Clinton River, the more recent 1973 modeling analysis was not included in this review because the pre-improvement survey was conducted at a flow in excess of 10 times the post-improvement survey flow. In the case of Hurricane Creek, the up-dated model was calibrated against post-improvement water quality data and therefore, would not be a true test of the model. With respect to the Cibolo Creek, the state of Texas is now in the process of recalibrating the model against the post-operational water quality data.

A variety of "off the shelf" water quality modeling programs were used by the original analyses in the wasteload allocation studies. These models were AUTOQUAL (Patuxent), RIVER (Wilsons Creek), CADEP (Hurricane Creek), QUAL I expanded (Cibolo Creek), desktop solutions (Clinton River) and HRM (Hudson River). Although each computer program is slightly different, they are all based on similar theoretical developments.

For background information, the results of the original model calibration and low flow dissolved oxygen projections (wasteload allocations) are presented on Figures 4.1 and 4.2.

On these figures, model results are plotted as solid lines and observed data are plotted as circles (mean) and ranges (variation over day). As is

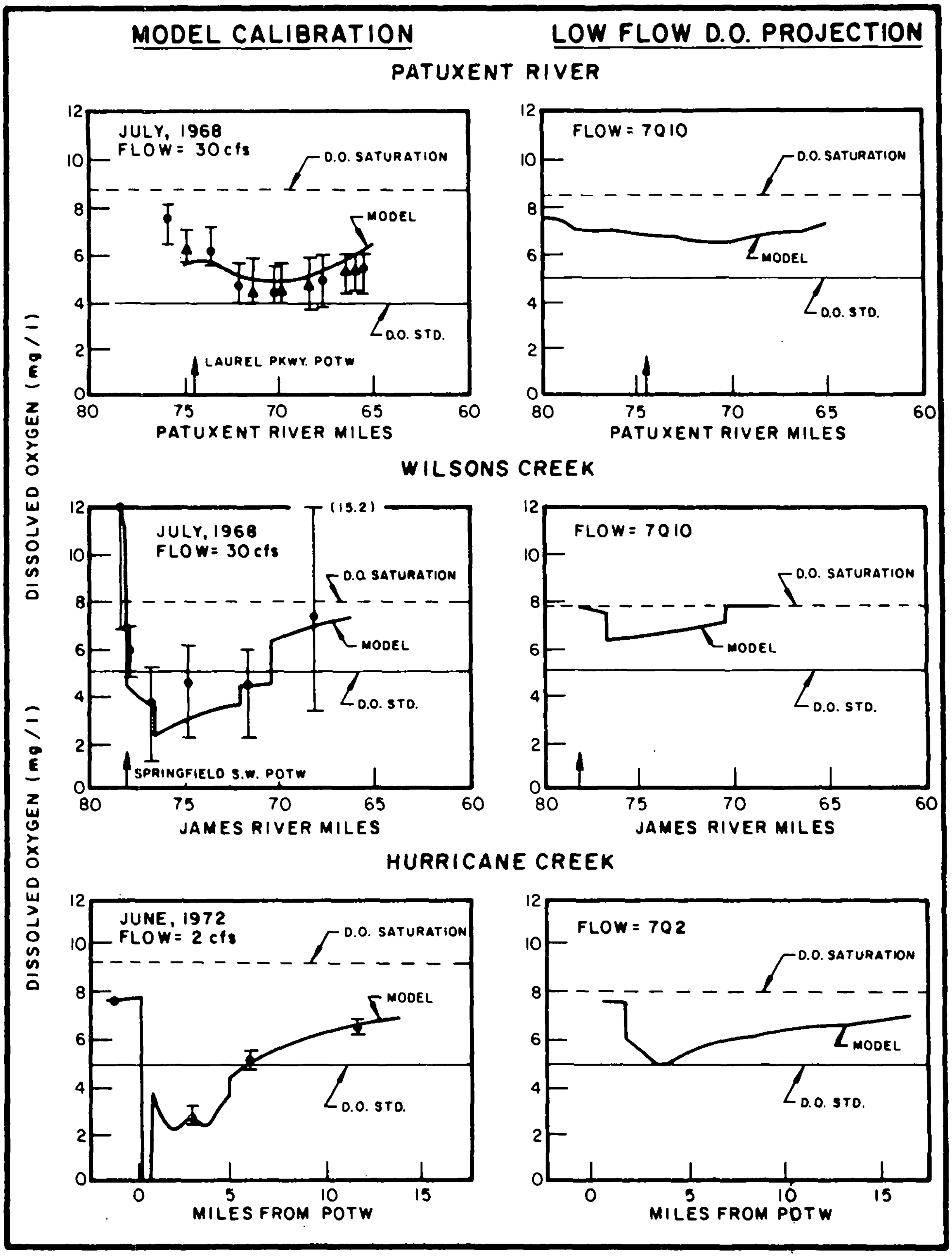


Figure 4.1

Model Calibration Analyses and AWT Low Flow Dissolved Oxygen Projections

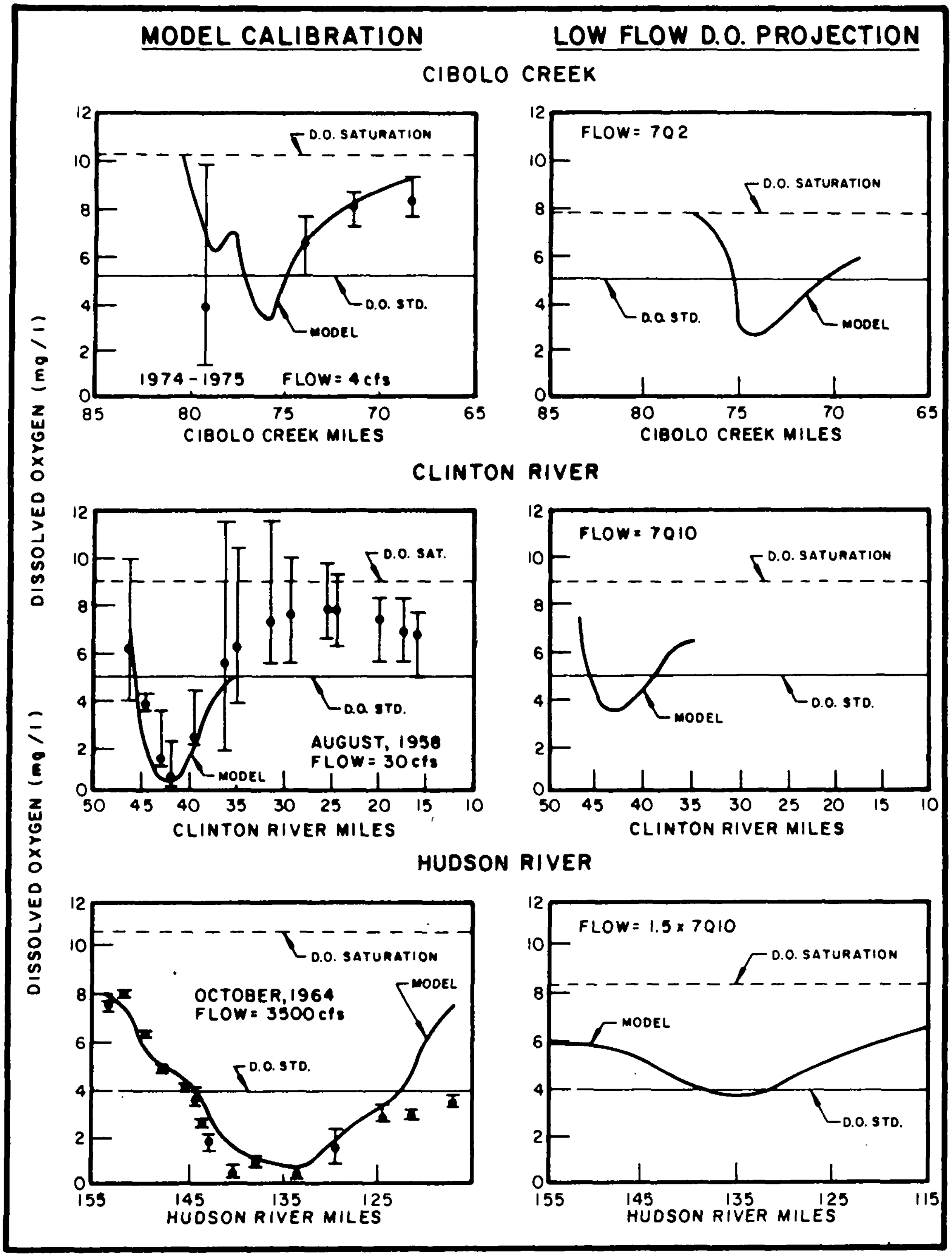


Figure 4.2

Model Calibration Analyses and AWT Low Flow Dissolved Oxygen Projections illustrated on these figures, model calibration results reasonably reproduce observed mean dissolved oxygen field sampling data. For each river, both observed and calculated oxygen data are less than the dissolved oxygen water quality standard. Treatment levels for each POTW during calibration analyses were primary (Hudson) or a form of secondary treatment. Flows and temperatures were near critical flows and temperatures. Quantitative measures of "goodness of model fit" are presented in Section 4.2 of this chapter.

Also presented on each figure for the background information are the results of dissolved oxygen projections at drought flows and temperatures. Point source effluent conditions for projections represent year 1990 or 2000 plant flows and good carbon removal as well as inplant nitrification for all POTWs except those located on the Clinton River. Clinton River point source loadings are established based on good CBOD removal only. Effluent conditions for water quality projections are presented in Table 4.1.

For the Patuxent River, Wilsons Creek, and Hurricane Creek, the results indicate that the projects increase dissolved oxygen concentrations to levels which comply with water quality standards. In Cibolo Creek, the Clinton River, and the Hudson River, the projects as designed are projected to cause some violations of dissolved oxygen standards at critical conditions.

The following section presents tests of each of these calibrated models against post-improvement dissolved oxygen data which was collected after treatment was upgraded from pre-operational levels. Statistical methods are used to quantify "goodness of model fit."

4.2 Post-improvement Model Evaluations

New treatment facilities were constructed in all six river basins discussed in Section 4.1. In three basins (Patuxent, Wilsons and Clinton), POTWs were upgraded to treatment levels beyond secondary. On the Main Stem Patuxent, the Laurel Parkway facility was upgraded to secondary treatment with nitrification

TABLE 4.1

PROJECTION POTW EFFLUENT CHARACTERISTICS

River	POTW	Flow (mgd)	BOD_5 (mg/l)	Ammonia (mg/l)
1. Main Stem Patuxent	Maryland City	2.70	10.0	3[a]
	Laurel Parkway	6.40	10.0	3[a]
2. Wilsons Creek	Springfield Southwest	19.00	10.0	1
3. Hurricane Creek	Hurricane Creek	1.55	5.0	2[b]
4. Cibolo Creek	ODO J. Riedal	5.82	5.0	2
5. Clinton River	Pontiac Area Point loads	19.40[c]	11.7	-[d]
6. Hudson River	Albany Area Point Loads	34.50[c]	30.0[e]	10[d]

[a]Total nitrogen (assumed as ammonia)

[b]TKN (assumed as ammonia)

[c]Post-operational flow

[d]Not considered in original projections

[e]90% BOD and 50% NH_3 removal

and effluent polishing. On the Clinton River, both the Pontiac and East Boulevard POTWs were upgraded to secondary treatment with phosphorus removal. For the other three rivers, treatment was upgraded to good secondary. In each river, however, the given POTWs were achieving a high degree of inplant nitrification at the time of the post-improvement water quality survey.

One evaluation made as part of this study, was to test the calibrated water quality model by calculating post-improvement river dissolved oxygen concentration. To do this, physical parameters of stream cross-sectional area, depth, velocity, or time of travel were adjusted to post-improvement river flow conditions. Relationships developed during the model calibration analyses were used as guidelines for setting these parameters. Next, low flow projection CBOD oxidation coefficients and NBOD oxidation coefficients developed by the original analysts were adjusted to post-operative temperature conditions. Models were then set-up with segmentations the same as those used by the original analysts. Where possible, the same computer modeling programs as those discussed earlier were used for evaluations. Because not all of these models were available to HydroQual within the constraints of the project, substitutions of similar models were made for the Patuxent River, Hurricane Creek, and the Hudson River. Sparse Matrix Analysis Model (SPAM)[16] was substituted for HRM, RIVER[17] was substituted for AUTOQUAL and CADEP and QUAL II[18] was substituted for QUAL I (expanded version).

Treatment plant effluent values presented in Table 4.2 were then input to all models and dissolved oxygen profiles calculated. The results of these analyses are shown on Figure 4.3 as solid lines while observed dissolved oxygen field data are shown as circles. In general, the water quality models reproduced post-operational dissolved oxygen data with a reasonable degree of accuracy. In the Hudson River, the model underestimated dissolved oxygen by approximately 0.8 mg/l, while in Hurricane Creek the model overpredicted oxygen concentrations in excess of 1.5 mg/l. For each of the other rivers, the model results compare favorably with observed data.

TABLE 4.2

POST-OPERATION POTW EFFLUENT CHARACTERISTICS

River	POTW	Flow (mgd)	BOD_5 (mg/l)	Ammonia (mg/l)
1. Main Stem Patuxent	Maryland City	0.48	10.0	15.0
	Laurel Parkway	4.50	1.0	0.3
2. Wilsons Creek	Springfield Southwest	24.70	3.6	1.5
3. Hurricane Creek	Hurricane Creek	0.64	4.7	1.4
4. Cibolo Creek	ODO J. Riedal	2.00	7.3	4.8
5. Clinton River	a. East Boulevard	3.20	5.0	0.2
	b. Auburn	17.60	4.0	1.1
6. Hudson River	a. Albany North	15.00	8.1	0.1
	b. Albany South	19.50	8.5	0.1

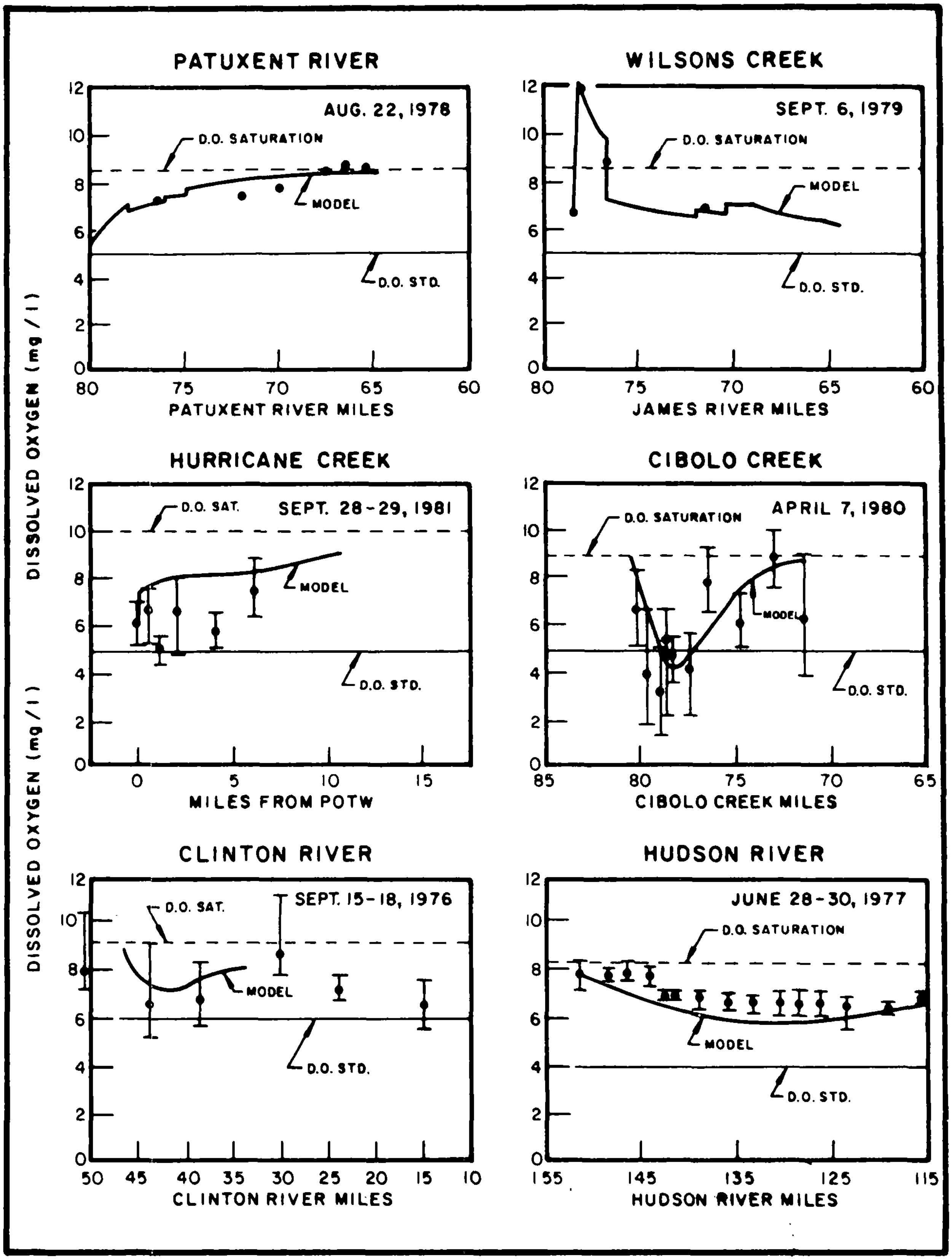


Figure 4.3

Comparisons of Model Results and Postimprovement Dissolved Oxygen Data

The RMS error (Equation 4.1), a quantitative measure of the "goodness of fit" of the models against pre- and post-improvement field data was then calculated using Equation 4.1.

$$RMS = [(\Sigma (D.O._o - D.O._c)^2/N]^{1/2} \tag{4.1}$$

where:

RMS = root mean square error (mg/l)

DO_o = observed D.O. (mg/l)

DO_c = calculated D.O. (mg/l)

N = number of data observations in the stream

The RMS errors for each river are summarized on Figure 4.4 for both calibration and post-improvement analyses. The post-improvement RMS error across all six rivers is about 0.94 mg/l. Cibolo Creek and Hurricane Creek show the largest RMS errors at 1.8 and 1.95 mg/l, respectively. As shown on Figure 4.3, the RMS error for Hurricane Creek originates from an over-prediction of observed data. Cibolo Creek errors stem from the model over-predicting data at some locations and under-predicting at other locations. Root Mean Square errors are slightly less, as shown on Figure 4.4 for model calibration analyses. The average RMS error across all rivers in the calibration analyses is about 0.67 mg/l.

An additional measure of "goodness of fit" for pre- and post-operational model analyses is presented on Figure 4.5 as a regression of computed dissolved oxygen against observed dissolved oxygen. On this figure, the solid line represents where calculated model output equals observed calibration or post-improvement dissolved oxygen data. The general trend, is for the model calibration results to yield an extremely good representation of observed field data. This is caused by the flexibility in calibration procedures of being free to adjust model results to obtain the best fit of observed data.

In the post-improvement regression, a number of factors are evident from Figure 4.5(b). First, the objective of increasing dissolved oxygen

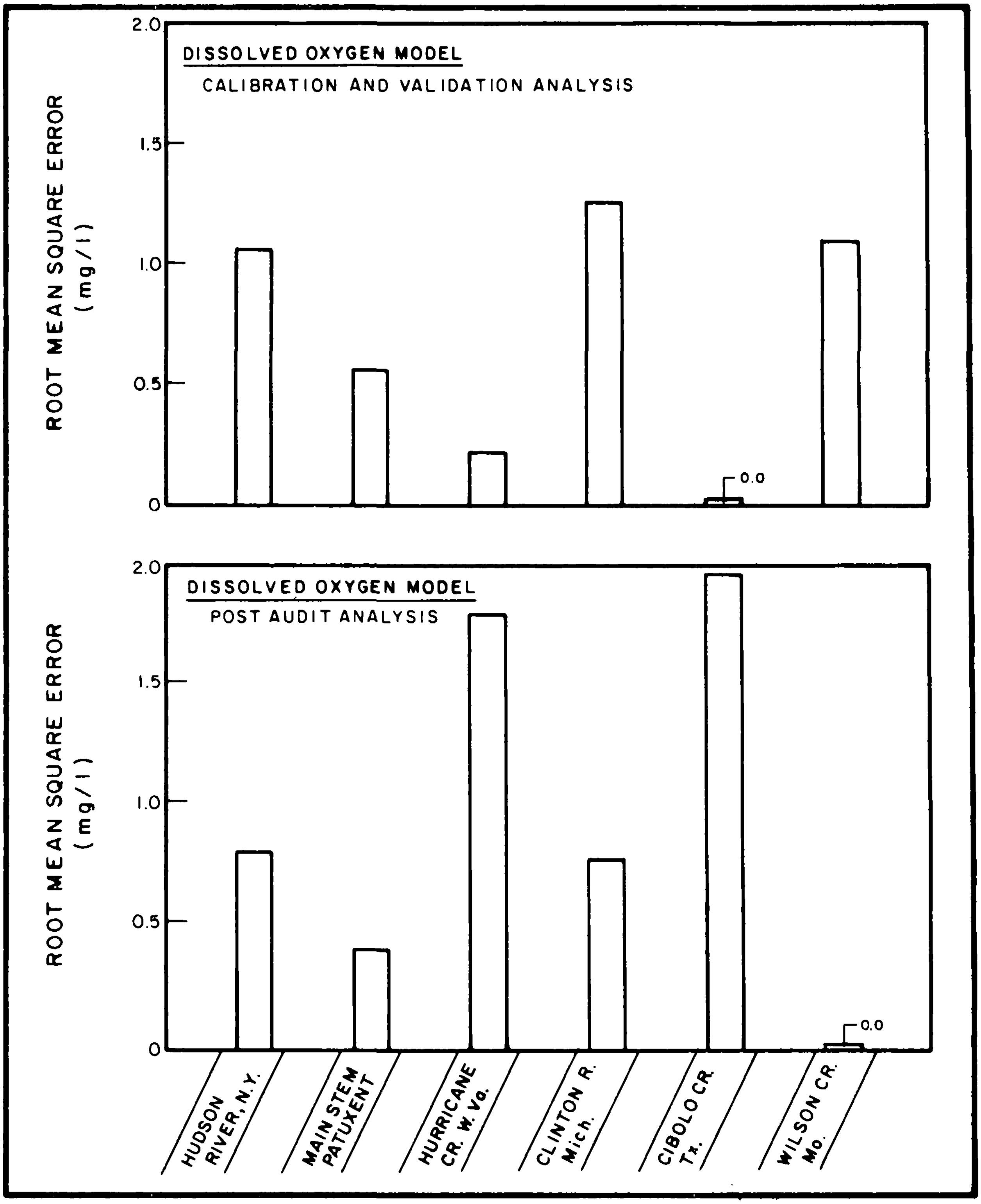


Figure 4.4

Summary of Model Errors

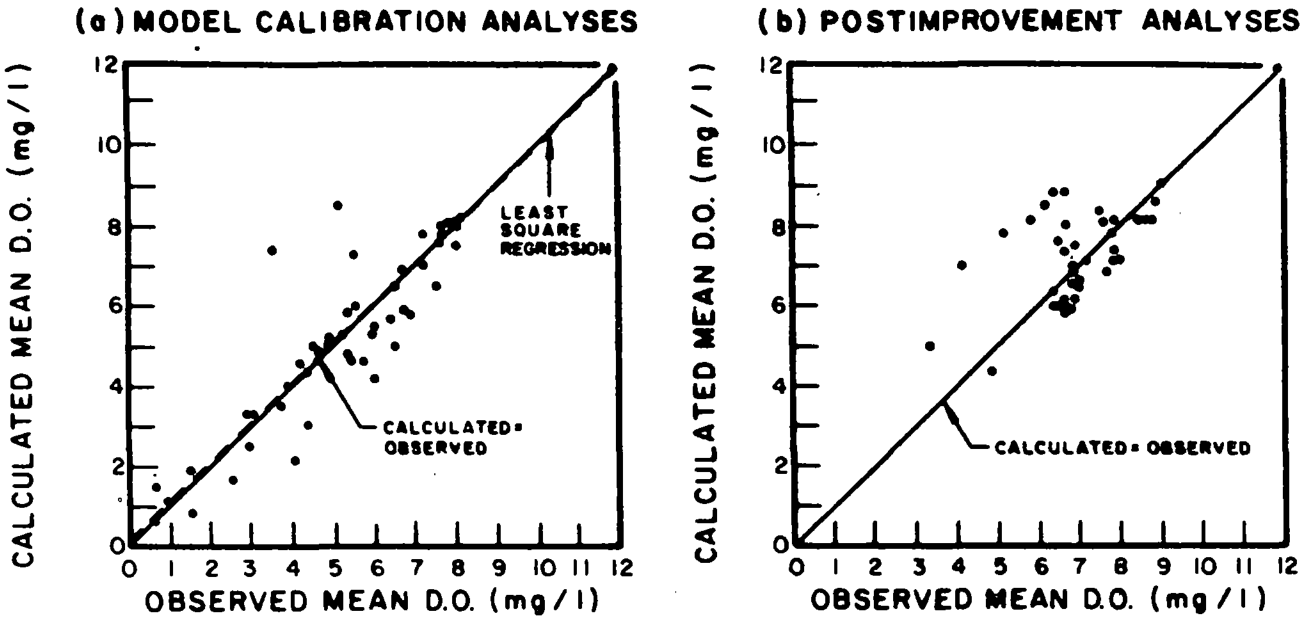


Figure 4.5

Regression of Calculated and Observed Dissolved Oxygen Concentrations

concentrations in all rivers was achieved. This can be seen by the fact that almost all of the dissolved oxygen data exceed 5.0 mg/l. Second, with the exception of a few data points, the data fall near the line representing a perfect correlation between computed and observed data. Those data which are above the solid line are mostly from Hurricane Creek where the results were over optimistic. In general, however, there is more scatter between observed and calculated post-improvement data than for the comparison during model calibration.

In summary, model testings indicate that goals of improving dissolved oxygen levels as calculated by post-improvement models generally are confirmed by field sampling data. The RMS errors calculated during the post-improvement model testings were between 0.0 and 0.8 mg/l for four of the six rivers evaluated. Root mean square dissolved oxygen errors for the other two rivers were between 1.5 and 2.0 mg/l. For one of these rivers, the error was biased towards the model over-predicting observed data, while for the other river there was no bias and over-prediction, and under prediction errors were about equal.

Explanation as to why the post-improvement models did not perform as well as pre-operational models requires detailed evaluation of the model calibration analysis which was beyond the scope of this project. As discussed in Section 4.3 which follows, one potential reason is that post-improvement CBOD instream oxidation rates tend to be less than pre-operational rates. However, other possible reasons which can exist are assignment of a $CBOD_{ult}$ to BOD_5 ratio to POTW effluents which is not confirmed by time series BOD testing (Section 4.4); inadequate spatial water quality data (Cibolo Creek); combined CBOD and NBOD reactions (Hurricane Creek, Clinton River); or inadequate definition of other model components such as stream depth and velocity, SOD and algal influences.

4.3 Coefficient Evaluation

The CBOD oxidation rates, ammonia or NBOD oxidation rates, and dissolved oxygen reaeration rates used in model calibration analyses for the six rivers discussed in the preceding sections are summarized in Table 4.3. The CBOD oxidation rates used in the calibrations range from 0.10/day (base e, 20°C) to 2.2/day while nitrification rates range from 0.0/day to 0.5/day. In all studies except the Hudson River, oxidation rates used in wasteload allocation studies were equal to oxidation rates developed during model calibration analyses. Hudson River nitrification rates for projections were 0.25/day while for calibration of the model they were 0.0/day.

In post-operational testing of the six available models (Section 4.2), CBOD and ammonia oxidation rates were set equal to model calibration rates. Resulting dissolved oxygen calculations (Figure 4.3) were reasonably accurate when compared to observed dissolved oxygen data. Although the models reproduce dissolved oxygen data, reductions in the RMS errors can be achieved through changes in CBOD and NBOD oxidation rates for a few of the water bodies.

Clinton River: CBOD oxidation rates for post-operative studies[21] as shown on Figure 4.6(a) are reduced from pre-operative rates of 2.2/day to about 0.2/day. As shown on Figure 4.6(b), nitrification is occurring at a rate of about 2.5 to 3.8/day based on 1973 and 1976 data. Pre-operational analyses indicated a nitrification rate of 0.0/day would best fit the dissolved oxygen profiles.

Patuxent River: Figure 4.6(c) presents pre- and post-operational BOD_5 and NBOD mass plots in the Patuxent River. Although the rates derived from these data[22] are slightly different than those shown in Table 4.3, a reduction in rates appears to occur after treatment is upgraded.

Hudson River: Figure 4.7 shows instream BOD_5 data as solid circles. The solid line represents model calculations at the calibration oxidation rate of 0.25/day. A reduction of this rate to 0.15/day (dashed line) provides a much better reproduction of instream BOD_5 data. When this rate is used to calculate dissolved oxygen (not shown), the RMS error is reduced to 0.0 mg/l.

TABLE 4.3

SUMMARY OF MODEL CALIBRATION AND PROJECTION COEFFICIENTS

River	BOD Decay Rate (1/Day)		NBOD Decay Rate (1/Day)		Reaeration Rate (1/Day)	
	Calibration	Projection	Calibration	Projections	Calibration	Projections
Main Stem Patuxent	0.37-0.50	0.37-0.50	0.17-0.43	0.17-0.43	O'Connor-Dobbins[a]	O'Connor-Dobbins
Wilsons Creek	0.3	0.3	0.4	0.4	O'Connor-Dobbins	O'Connor-Dobbins
Hurricane Creek	0.10-0.50	0.10-0.50	0.10-0.50[b]	0.10-0.50	0.6-2.5	0.5-2.5[c]
Cibolo Creek	0.18	0.18	0.25	0.25	Owens-Gibbs[d]	Owens-Gibbs
Clinton River	2.2	2.2	0	0	-[e]	-
Hudson River	0.25	0.25	0	0.25	O'Connor-Dobbins	O'Connor-Dobbins

[a] O'Connor - Dobbins equation[19]

[b] CBOD and NBOD modeled together with a single rate

[c] Believed to be a calibration parameter

[d] Owens - Gibbs equation[20]

[e] Data unavailable but reaeration was a calibration parameter

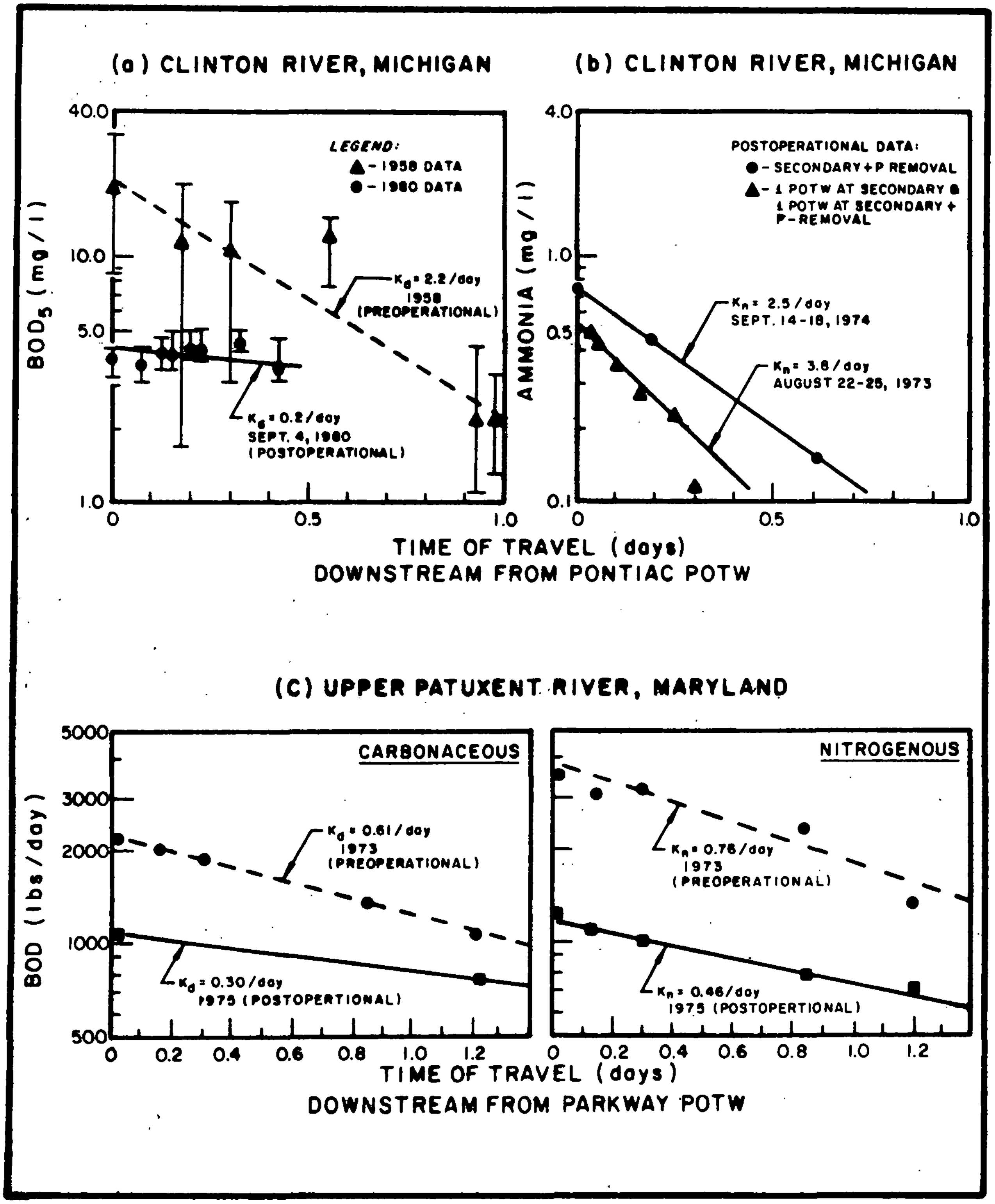


Figure 4.6

Evaluation of Treatment Changes on Oxidation Rates

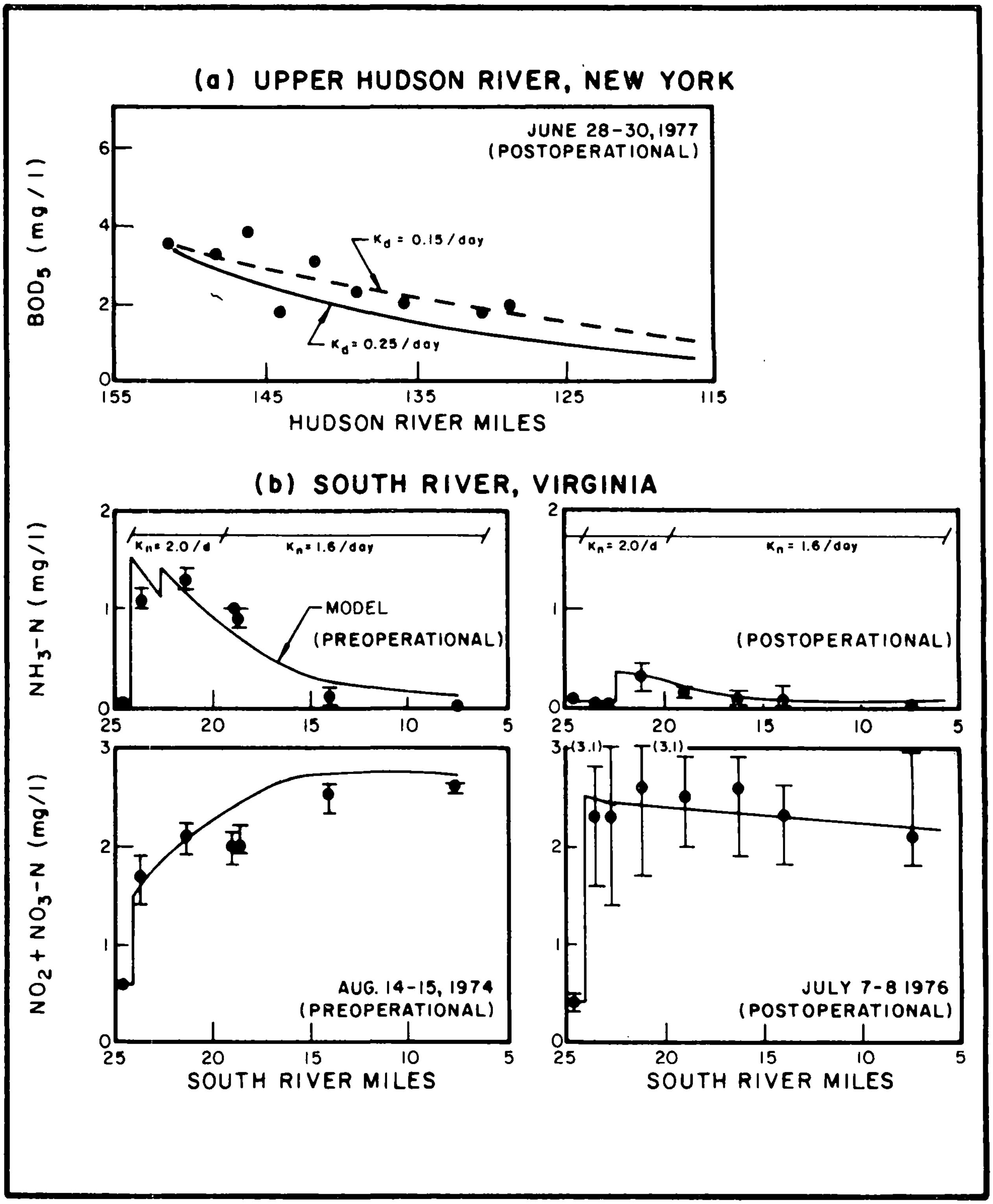


Figure 4.7

Evaluation of Treatment Changes on Oxidation Rates

Hurricane Creek: A detailed water quality modeling analysis[15] using the 1981 field data developed a CBOD oxidation rate of 0.35/day, a nitrification rate of 0.7/day and a reaeration rate calculated using the Tsivoglou-Neal[23] from the dissolved oxygen, BOD, and ammonia concentration profiles. The nitrification rate is slightly higher than used in the pre-improvement model calibration while the CBOD decay rate is about the same.

South River: Although a post-improvement model testing was not performed for this river, data were available to evaluate pre- and post-operational nitrification rates. These data are presented on Figure 4.7(b) as solid circles. The solid lines on each figure are the result of calculations performed with a model developed by USEPA, Region III. The nitrification rates are also shown on the figure. This analysis indicates that instream nitrification rates (1.6 to 2.0/day) did not change after treatment was upgraded.

Wilsons and Cibolo Creeks: Field data from Wilsons Creek and Cibolo Creek indicate that post-operational oxidation rates were equal to oxidation rates developed in the calibration analyses.

A summary of pre- and post-operational oxidation coefficients is presented in Table 4.4. Three sets of oxidaton coefficients show changes after treatment was upgraded while three sets of rates remain the same. Carbonaceous oxidation rates which changed after upgrading, are reduced on the average of 60 percent. Where nitrification rates changed the Patuxent River rate decreased, while rates in Hurricane Creek double, and rates in the Clinton River increased from 0.0/day to in excess of 2.0/day.

Concepts which have been postulated with respect to treatment changes influencing reaction rates include:

a. High levels of sewage treatment remove easily degraded carbonaceous material and leave only refractory materials in POTW supernatants. These refractory materials are difficult to degrade and resulting stream oxidation rates are reduced when streams are exposed to these materials.

TABLE 4.4

SUMMARY OF PRE- AND POST-IMPROVEMENT OXIDATION RATES

River	Treatment	Pre-Improvement CBOD Oxidation Rate (1/day)	NBOD Oxidation Rate (1/day)	Treatment	Post-Improvement CBOD Oxidation Rate (1/day)	NBOD Oxidation Rate (1/day)
Main Stem Patuxent	Secondary	0.61[a]	0.76[a]	Secondary and Nitrification	0.30[a]	0.46[a]
Wilsons Creek	Secondary	0.30	0.40	Secondary and Nitrification and Polishing	0.30	0.40
Hurricane Creek	Trickling Filter	0.10 - 0.50	0.10 - 0.50	Secondary[b]	0.35	0.70
Cibolo Creek	Secondary	0.18	0.25	Secondary[c]	0.18	0.25
Clinton River	Secondary	2.20	0	Secondary and P-Removal	0.20	2.5 - 3.8
Hudson River	Primary	0.25	0	Secondary	0.15	0
South River	Secondary	-	1.6 - 2.0	Secondary and Nitrification	-	1.6 - 2.0

[a]From reference(23) not from calibration analysis

[b]Oxidation ditch achieving nitrification

[c]New facility achieving nitrification

b. Ammonia in effluents has the same degradeability characteristics whether the effluent concentration is 10.0 or 4.0 mg/l. Therefore, if nitrification is occurring in the stream, it is not likely that changes in POTW treatment will influence the rate of nitrification.

c. High levels of sewage treatment result in long sludge ages which produce high levels of bacteria in POTW effluents. These higher forms of bacteria may be capable of carrying on instream nitrification where lower forms of bacteria in poorly treated effluents cannot carry on nitrification.

It is not clear from these data that any trends exist which confirm or refute any of these theories. One reason for the lack of any finite trends, is the lack of before and after improvements rate information. Another reason is the quality of the rate information which does exist. For example, CBOD oxidation rates are often based on evaluation of instream BOD_5. Much data exists to show that the BOD_5 test can often include oxidation of ammonia. Where this is true, the analyst has not developed a technically sound CBOD oxidation rate which can realistically be used to compare against other rates for evaluation of any changes.

Without definition of changes in these rates an amount of uncertainty will always exist when performing wasteload allocation modeling. The only way to minimize this uncertainty is to gather reaction rate data from post-improvement field surveys. A recommendation, therefore, is that post-improvement model testing and field data surveys continue so that the oxidation rate data base, particularly for highly treated effluents, can be expanded in order to improve dissolved oxygen projection modeling. From an expanded data base, trends which may exist between treatment levels and oxidation rates may become more apparent. Identification of any such trends will aid future analysts to develop dissolved oxygen projections which will be more accurate than those presented here.

4.4 POTW Effluent Quality

During this project information was compiled to assess effluent BOD_5, $CBOD_5$, ammonia, ultimate CBOD to BOD_5 ratios, and ultimate CBOD to $CBOD_5$ ratios from POTWs operating at various levels of treatment. These data originated from HydroQual technical files, USEPA technical documents,[25] professional papers,[26] and various other literature sources summarized in Appendix B. In total, information on these parameters was available for approximately 114 treatment facilities.

Since these data originate from various modeling programs and they were not scientifically collected to assess effluent concentrations, care should be exercised when evaluating the following results. First, much of the data were taken during warm weather periods when most treatment facilities are operating well. Second, as shown in Table 4.5 data from certain treatment facilities are sparse. With these facts in mind, however, some qualitative information can be gained from the review which follows.

Effluent BOD_5, $CBOD_5$ and ammonia concentrations for POTWs where information on treatment type was available are presented on Figure 4.8 and Table 4.5. These data indicate that secondary and advanced effluents are characterized by effluent BOD_5 concentrations which are substantially less than primary and trickling filter plant effluent concentrations. Effluent BOD_5 concentrations from some 38 secondary treatment facilities average 19.1 mg/l with a standard deviation of about 16.3 mg/l.

Effluent $CBOD_5$ concentrations from 24 of these secondary treatment facilities average 10.3 mg/l with a standard deviation of 6.4 mg/l. These BOD_5 and $CBOD_5$ concentrations are significantly different based on a "t" test at a 90 percent confidence level. This information tends to reinforce findings[26] that significant nitrification is occurring during the BOD test for many secondary treatment POTWs.

TABLE 4.5

SUMMARY OF EFFLUENT CHARACTERISTICS

Treatment Type	Number of Locations[a]	POTW Effluent Concentrations (mg/l)					
		BOD_5		$CBOD_5$		Ammonia-N	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Primary	2	101.0	21.2	-	-	-	-
Trickling Filter	13	41.2	27.8	-	-	16.6	12.2
Secondary	38	19.1	16.3	10.3	6.4	8.9	6.3
Secondary + P-Removal	9	16.2	14.0	14.6	9.3	7.9	8.9
Secondary + Nitrification	10	11.5	11.8	4.8	3.9	1.0	1.4
Secondary + P-Removal + Nitrification	3	13.6	18.6	-	-	0.9	0.7
Secondary + Nitrification + Filters	3	3.9	2.0	-	-	4.8	8.2

[a]Number of locations with BOD_5 data, in some cases number with $CBOD_5$ or NH_3 data may be less

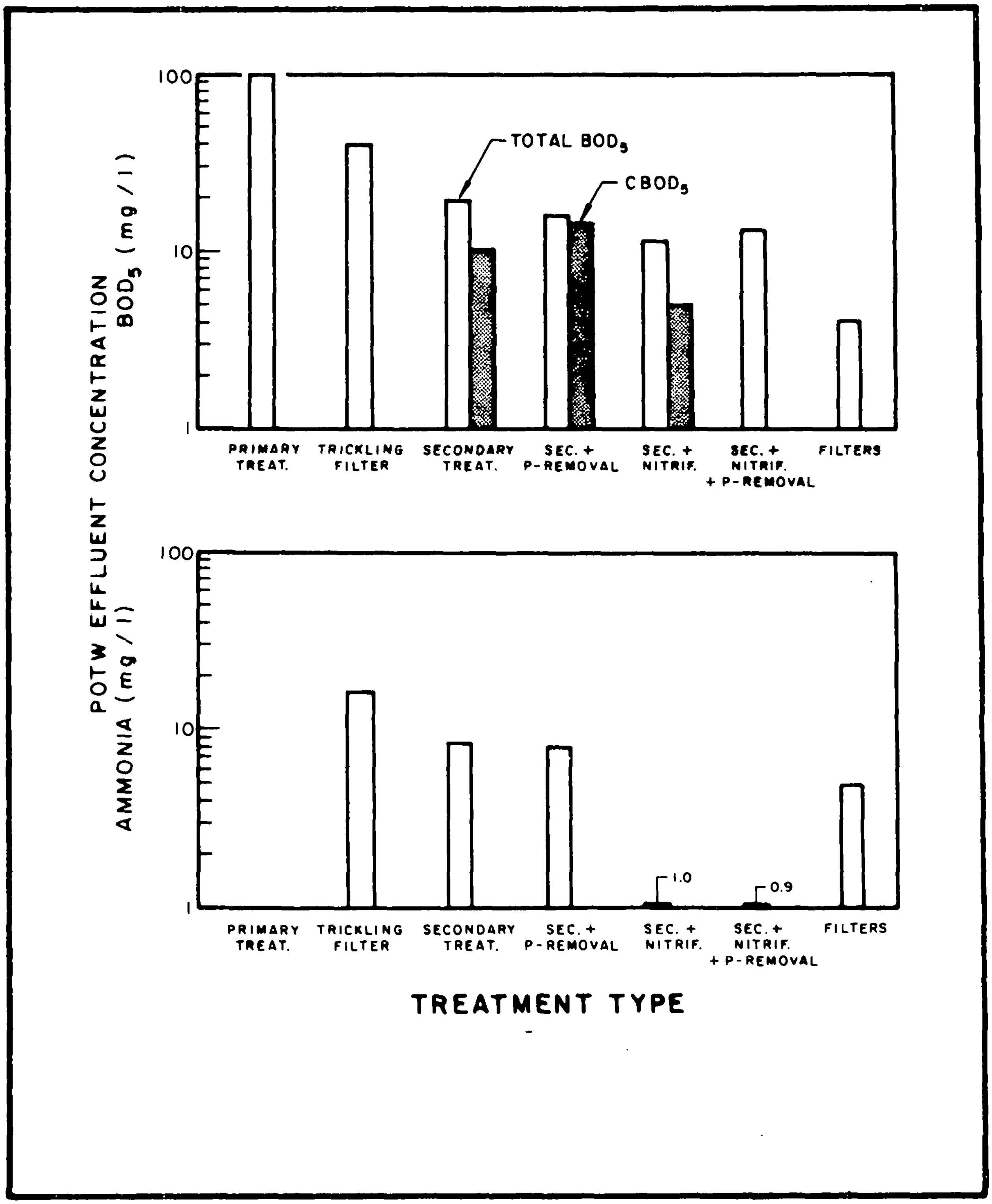


Figure 4.8

POTW Effluent Characteristics

A similar difference between effluent BOD_5 and $CBOD_5$ concentrations are not observed for secondary facilities which are removing phosphorus from their effluents. This may be because phosphorus removal unit processes also remove nitrifying bacteria from the effluent stream. Additional data is needed to substantiate this conclusion.

For secondary treatment facilities with nitrification processes, major differences again are observed between effluent BOD_5 and $CBOD_5$ concentrations. Effluent data available for 10 of these facilities show a mean BOD_5 concentration of 11.5 mg/l with a standard deviation of 11.8 mg/l. Effluent $CBOD_5$ data available for seven of these POTWs have a mean concentration of 4.8 mg/l with a standard deviation of 8.2 mg/l.

Information available for facilities with both nitrification and phosphorus removal processes and facilities with effluent polishing filters, exhibit effluent BOD_5 concentraton of 13.6 and 3.9 mg/l, respectively. A sufficient amount of data were not available to assess effluent $CBOD_5$ concentration.

Figure 4.8 also presents effluent ammonia concentration by treatment type. For the 26 secondary treatment facilities effluent ammonia averaged 8.9 mg/l with a standard deviation of 6.3 mg/l. These data which were gathered from summer sampling information during intensive water quality surveys, give credence to the fact that many secondary POTWs achieve some nitrification during summer periods. It is likely that with inplant nitrification occuring, nitrifying bacteria present in the effluent can cause oxygen consumption during the BOD_5 test. The BOD_5 test would therefore tend to under estimate the ability of the POTW to remove carbonaceous oxidizing materials.

These data also show ammonia-N effluent concentrations for POTWs designed to nitrify (secondary plants with nitrification) average 1.0 mg/l or less with a standard deviation of about 1.0 mg/l. A summer effluent ammonia concentration for nitrifying POTWs therefore of about 1.0 mg/l appears to be a reasonable estimate for planning purpose.

Table 4.5 presents a summary of the effluent information discussed above. These data may prove to be useful in reviews or in facility wasteload allocation impact analyses. These data do not represent an exhaustive search of all available sources; however, they may prove useful along with other available effluent concentration measurements to allow analysts to develop reasonable summer effluent concentrations to employ in water quality analyses.

Data were also available from the 144 POTWs to assess the ratio of effluent ultimate CBOD to BOD_5 or $CBOD_5$. This ratio is required in dissolved oxygen modeling analyses to estimate POTW ultimate oxygen demand from effluent BOD_5 or $CBOD_5$ data. A summary of this information is presented in Table 4.5 and on Figure 4.9.

Historically, the ratio of $CBOD_{ult}$ to BOD_5 has been assumed as 1.5 for secondary and highly treated effluent. These data indicate 2.47 to be a better estimate of this ratio. A $CBOD_{ult}$ to $CBOD_5$ ratio of 2.84 was also developed from the data on Figure 4.9. The standard deviation for these two ratios is 1.52 and 1.17, respectively. These data indicate that the ratio can vary considerably, not only between different treatment levels but also between different sites with the same treatment levels. These data suggest that it is important to determine the ratio for each facility. This may not be possible where projected treatment conditions are significantly different than current conditions.

These data also show a difference in standard deviations of 1.52 and 1.17 for Figure 4.9(a) and 4.9(b), respectively. This may in part be because Figure 4.9(a) is derived from the ratio of $CBOD_{ult}$ to BOD_5 and Figure 4.9(b) is based on the ratio of $CBOD_{ult}$ to $CBOD_5$ data. As mentioned earlier, much data are available to show that nitrification can occur in the BOD_5 test, especially for municipal POTW effluents. When this occurs, the ratio of $CBOD_{ult}$ to BOD_5 could vary randomly. The reduced standard deviation associated with $CBOD_{ult}$ to $CBOD_5$ data may in part reflect this occurrence.

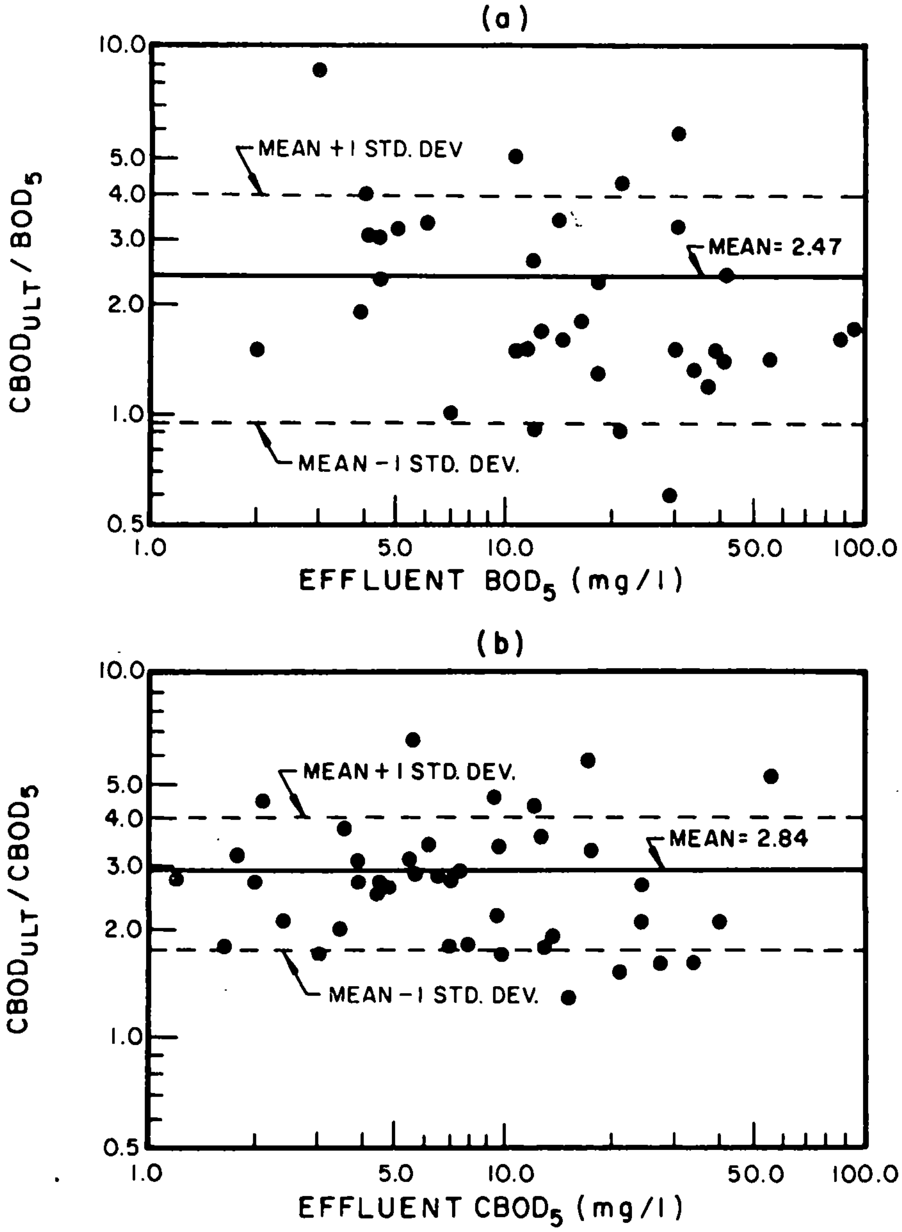


Figure 4.9

POTW Effluent Ultimate CBOD as a Function of $CBOD_5$ and BOD_5

Another reason the ratio of $CBOD_{ult}$ to BOD_5 or $CBOD_{ult}$ to $CBOD_5$ can vary is associated with the BOD test itself. It is well known that the BOD test itself is an inaccurate test. Such phenomena as lags in the test can significantly affect the ratio. In a rigorous analysis of this ratio, it would be desirable that all tests are performed in a similar manner and hopefully by the same analyst.

A recent document,[27] presents suggested ranges for these ratios. A value of 1.5 ($CBOD_{ult}/CBOD_5$) is suggested for poor secondary effluents; 2.0 is suggested for good quality secondary effluents; and 2.3 is suggested for advanced treatment effluents. Data presented on Figure 4.9 indicate that these suggested ratios are reasonable to use when site specific data are not available.

The consequence of using a ratio which has not been developed from field data could be to understate the effect of the wastewater on stream oxygen concentrations. For example, an analyst may measure a secondary effluent BOD_5 of 10.0 mg/l and assign a $CBOD_{ult}/BOD_5$ ratio of 1.5 in a model calibration analysis. This combination would result in a calculated effluent $CBOD_{ult}$ of 15.0 mg/l (10.0 mg/l x 1.5). If the actual ratio was 3.0, the analyst would be understating the effluent $CBOD_{ult}$ by a factor of two (30.0 compared to 15.0 mg/l). In calibrating the model, the analyst will have to assign this error to another source of dissolved oxygen impact such as nonpoint loadings. Extrapolating to wasteload allocation conditions, this nonpoint source loading may cause the analyst to require higher levels of treatment which may actually be necessary. Depending on the approach taken, the understated effluent $CBOD_{ult}$ may have a variety of effects on the wasteload allocations. Because of the importance of this parameter and the observed variability in the ratio from site to site, it is recommended that site specific ratios be developed on a case by case basis.

SECTION 5.0

LONG TERM WATER QUALITY CHANGES

Improvements in water quality as a result of upgrading municipal treatment from secondary to advanced levels can only be fully assessed when the AWT facility reaches its design capacity flow. In most cases, POTWs are designed for project year 1990 or year 2000 flows. Since, the facilities evaluated in the preceding report sections may not be at design capacity, post-improvement water quality data represent short term improvements over pre-improvement water quality. However, a model can be used to more accurately predict water quality improvements with and without the treatment plant improvements when the plant reaches its design capacity. These model results are referred to as long term water quality improvements.

This section evaluates long term dissolved oxygen improvements using the calibrated water quality models. The questions addressed are:

a. When the POTW is at design (year 2000) effluent flow, what will dissolved oxygen concentrations in the stream be if the POTW is constructed as a secondary POTW?

b. When the POTW is at design effluent flow, what will dissolved oxygen concentrations in the stream be if the POTW is constructed as a secondary plus nitrification POTW?

To perform a long term assessment, water quality models were set up for POTW design flows and critical river flow and temperatures. Dissolved oxygen simulations were then developed with each POTW at secondary treatment and then at AWT. Uniform POTW characteristics summarized in Table 5.1 were used to calculate effluent loadings of oxygen consuming materials discharged to the respective rivers.

TABLE 5.1

SECONDARY AND AT EFFLUENT PARAMETERS
USED IN LONG TERM DISSOLVED OXYGEN EVALUATIONS

Secondary Treatment Effluent Characteristics
(Activated Sludge)

$CBOD_5$ = 20.0 mg/1

$CBOD_{ult}/CBOD_5$ = 2.0

Ammonia-N = 15 mg/1

$NBOD/NH_3$ = 4.57

Dissolved Oxygen = 5.0 mg/1

Advanced Waste Treatment Effluent Characteristics
(Secondary Treatment Plus Nitrification)

$CBOD_5$ = 5.0 mg/1

$CBOD_{ult}/CBOD_5$ = 2.5

Ammonia-N = 1.0 mg/1

$NBOD/NH_3$ = 4.57

Dissolved oxygen = 8.3 mg/1

The four rivers used in this analysis are the Patuxent River, Wilsons Creek, Hurricane Creek, and Cibolo Creek. The Laurel Parkway POTW on the Patuxent River has already been upgraded to nitrification. On Wilsons Creek, the Springfield Southwest POTW, has been upgraded to nitrification and effluent polishing. On Hurricane and Cibolo Creek, new upgraded secondary facilities have recently been constructed and wasteload allocation studies recently completed[16, 25] recommend further upgrading to AWT for both facilities.

Results of dissolved oxygen simulations calculated by these methods are presented on Figure 5.1. These analyses indicate that the dissolved oxygen standard of 5.0 mg/l is violated in all four rivers when design flows and

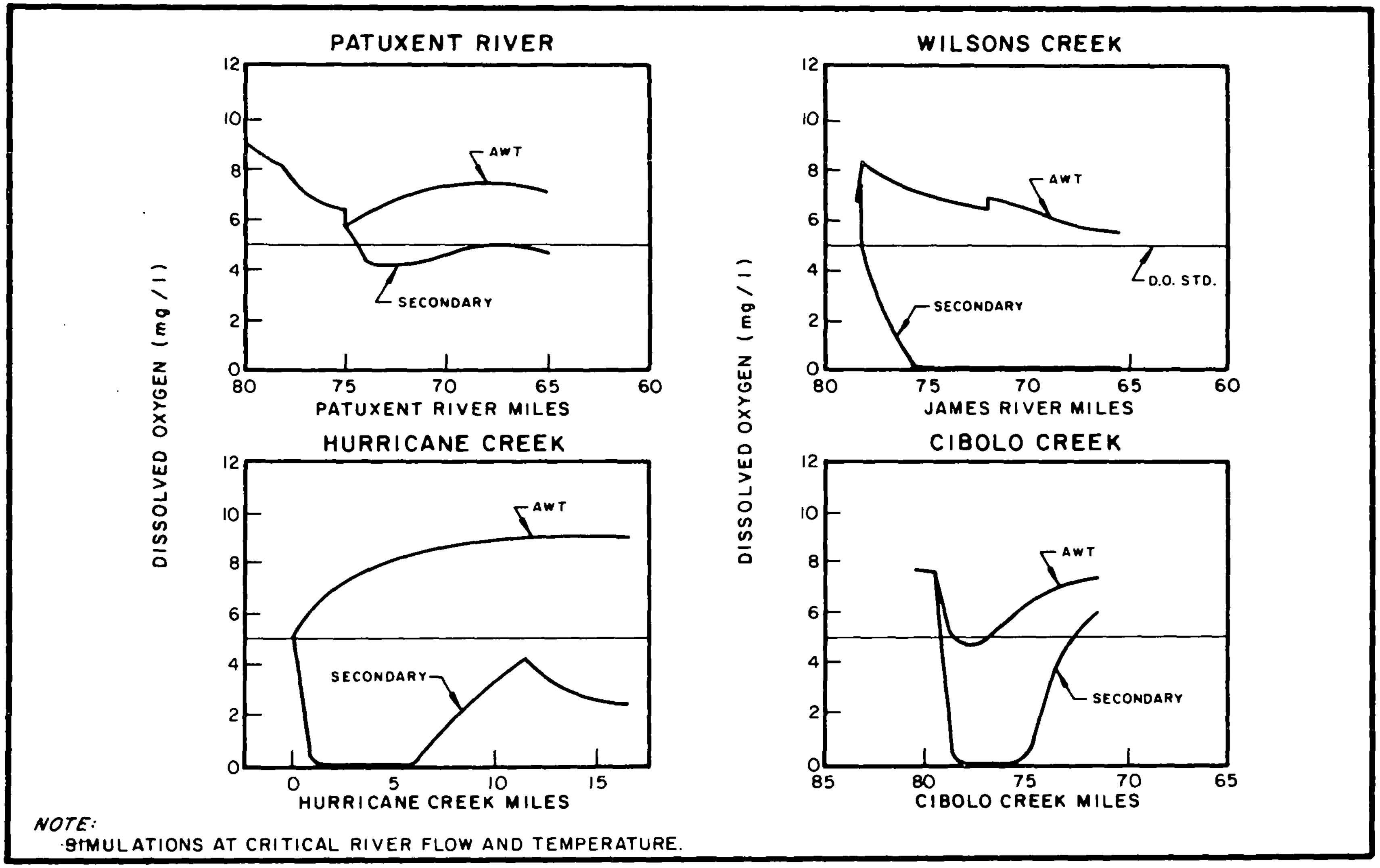


Figure 5.1

Calculated Long Term Dissolved Oxygen Changes critical river flows are reached and only secondary treatment is provided. At secondary treatment, dissolved oxygen concentrations in three of these rivers are projected to be at 0.0 mg/l for 5 to 10 river miles. When nitrification is provided at each facility, dissolved oxygen concentrations are projected to increase substantially and standards are only marginally violated in one of the rivers (Cibolo Creek).

Assuming that the model simulations are reasonably accurate, these results indicate that nitrification provides significant dissolved oxygen improvements in all four rivers. Further, if the project were not constructed and only secondary treatment were provided it is likely that daily average minimum oxygen concentrations of 0.0 mg/l would create unbalanced macroinvertebrate communities and unbalanced fish populations. In addition, it is also likely that during warm weather, anoxic conditions would have the potential to create odor problems.

In summary, nitrification in the effluent dominated streams are observed to have short term water quality improvements (Section 2.0). The model simulations also indicate the potential for additional long term water quality improvements, especially with respect to dissolved oxygen concentrations.

SECTION 6.0

SIMPLIFIED WATER QUALITY MODELING EVALUATIONS

In Section 4.0 of this report, six water quality models were tested against post-improvement field water quality data. These models were calibrated against water quality and physical river information collected before treatment was upgraded at the wastewater discharge facilities. The Hudson River, Patuxent River, and Hurricane Creek models were also verified against at least one data set other than the calibration data set. As shown on Figure 4.3, the models were able to reproduce water quality data collected after treatment was upgraded with a fair degree of accuracy.

Performing water quality modeling analyses such as those discussed in Section 4.0 generally requires a substantial effort. First, low flow intensive water quality and stream physical information must be collected by a trained field crew. Laboratory analyses must be conducted on the water samples collected in the field. All data must be reduced and a model must be calibrated against the field water quality data. For model accuracy, at least one other data set must be collected and used in a model verification analysis. Finally, model sensitivity analyses are performed and wasteload allocations are developed.

A complete wasteload allocation analysis including field sampling, laboratory analyses, and modeling for a river with a single point load may require on the order of 1000 man hours. More complex water bodies with model verification analyses may require in excess of 4000 man hours. Because such analyses can require substantial resources, efforts have been initiated to develop simplified wasteload allocation techniques which require a minimum amount of field sampling data and only desktop modeling calculations.

A recently published simplified technique[25] was developed by the USEPA. This chapter presents an overview of this technique and evaluates the technique in terms of data gathered as part of the previously discussed before and after studies.

6.1 Overview of a Simplified Wasteload Allocation Technique

A recently released simplified technique for performing wasteload allocations with minimum resources is the "Simplified Analytical Method For Determining NPDES Effluent Limitations for POTW's Discharging into Low Flow Streams."[25] This guidance was issued in September 1980 by the Monitoring Branch of the Office of Water Quality Regulations and Standards, (OWRS) USEPA, Washington, D.C. The document was also issued as Appendix A of another technical guidance document[27] issued in January 1981. In addition, an addendum to this method was issued jointly by OWRS and the Office of Water Program Operations on June 25, 1982. This addendum presents constraints on the procedures which are not presented in the original documentation.

The method for developing wasteload allocations is presented as "the simplest possible that will still allow the water quality manager to make a confident and defensible water pollution control decision." The method relies on a minimum amount of water quality and physical stream data most of which may exist based on previous studies. Basic data requirements are:

a. stream design flow (7Q10)
b. upstream water quality
c. stream physical characteristics
d. time of travel or velocity
e. effluent design flow
f. characteristics of design effluent

Using this information as well as a basic analytical equation for calculating instream dissolved oxygen, the guidance presents methods of selecting instream reaeration rates, BOD oxidation rates, NBOD oxidation rates, and SOD rates. The guidance does encourage collection of site specific data to define oxidation rates but, in the absence of such data, presents a method to determine applicable rates.

Rates are then input into the basic analytical equation to calculate a stream dissolved oxygen profile through the point of minimum dissolved oxygen. Effluent CBOD and NBOD concentrations are presented for secondary treatment and advanced treatment levels to use in calculating dissolved oxygen levels in the stream. Dissolved oxygen profiles are then compared to standards. The methodology then goes on to present methods to be used in incorporating wasteload allocation results into an NPDES permit.

The guidance document takes the user through the methodology in a clear concise way. It does require some understanding of water quality analyses and mathematical water quality modeling; however, the methodology does not rely heavily on the users judgment. By not relying on judgment, users of the documentation who have different levels of experience in water quality analyses, should end up with similar wasteload allocations.

6.2 Use of Analytical Techniques as a Decision Making Tool

Analyses were performed as part of this project to evaluate whether the simplified analytical method would produce similar wasteload allocations as were developed by other methods. These analyses were performed on 10 of the 13 water bodies discussed in Section 2.0.

It should be noted that the following constraints are placed on the analytical method by its authors:

a. The discharger must be a POTW receiving predominantly sanitary wastewaters. Any nonsanitary wastewaters in the treatment plants influent must exhibit essentially the same characteristics as sanitary wastewaters.

b. The discharge must be to a free-flowing stream in which the design low flow (usually 7Q10) is approximately equal to or less than the design discharge of the POTW.

c. The design discharge flow from the treatment plant must be 10 mgd (15.5 cfs) or less.

d. There is no significant interaction between the discharger being analyzed and any other upstream or downstream discharger.

e. The method may not be used to justify permit limitations more stringent than 10.0 mg/l $CBOD_5$ and 1.5 mg/l NH_3 (including filtration following nitrification). More stringent treatment must be supported by site specific data and sensitivity analyses.

In this analysis the constraints were widened so that the Hudson and Potomac Rivers (tidal water bodies), and the Blackstone River (POTW flow much less than stream flow) are the only rivers excluded from the analysis.

Stream reaction rates were developed from the guidance document and were used to calculate dissolved oxygen profiles for each of the 10 rivers at summer critical flows and temperatures. Analyses were performed assuming each POTW at either design secondary treatment or design secondary treatment plus nitrification. The results of these calculations are presented on Figures 6.1 and 6.2, and Table 6.1.

In these types of analyses there are two types of "errors" that may occur in the comparisons: the first error is an over estimation of the water quality improvement for a level of treatment. Therefore, water quality will be less than actually thought after treatment is installed and a water use interference may occur that was not predicted. The second error is an under estimation of water quality improvement resulting in over designed treatment facilities and an

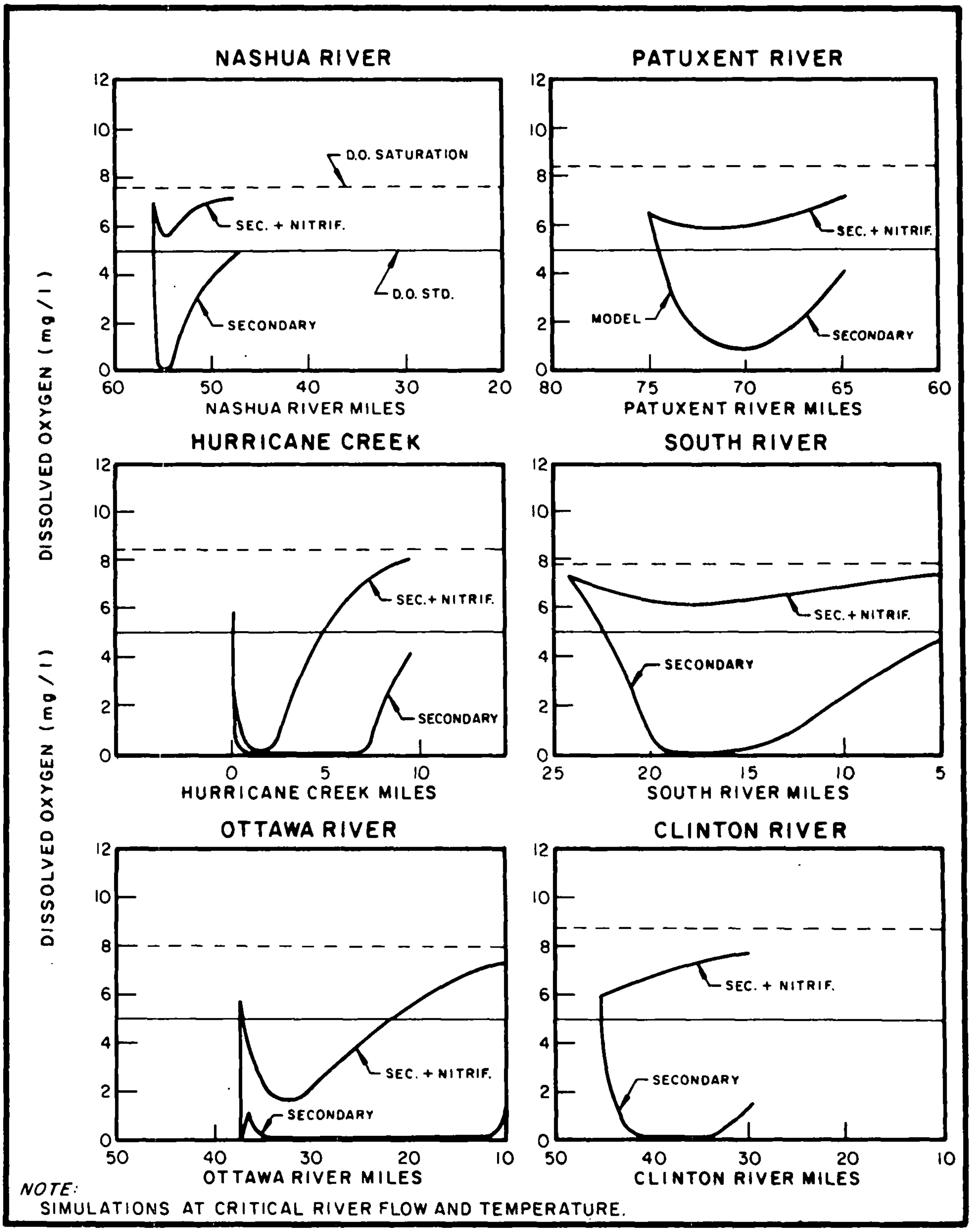
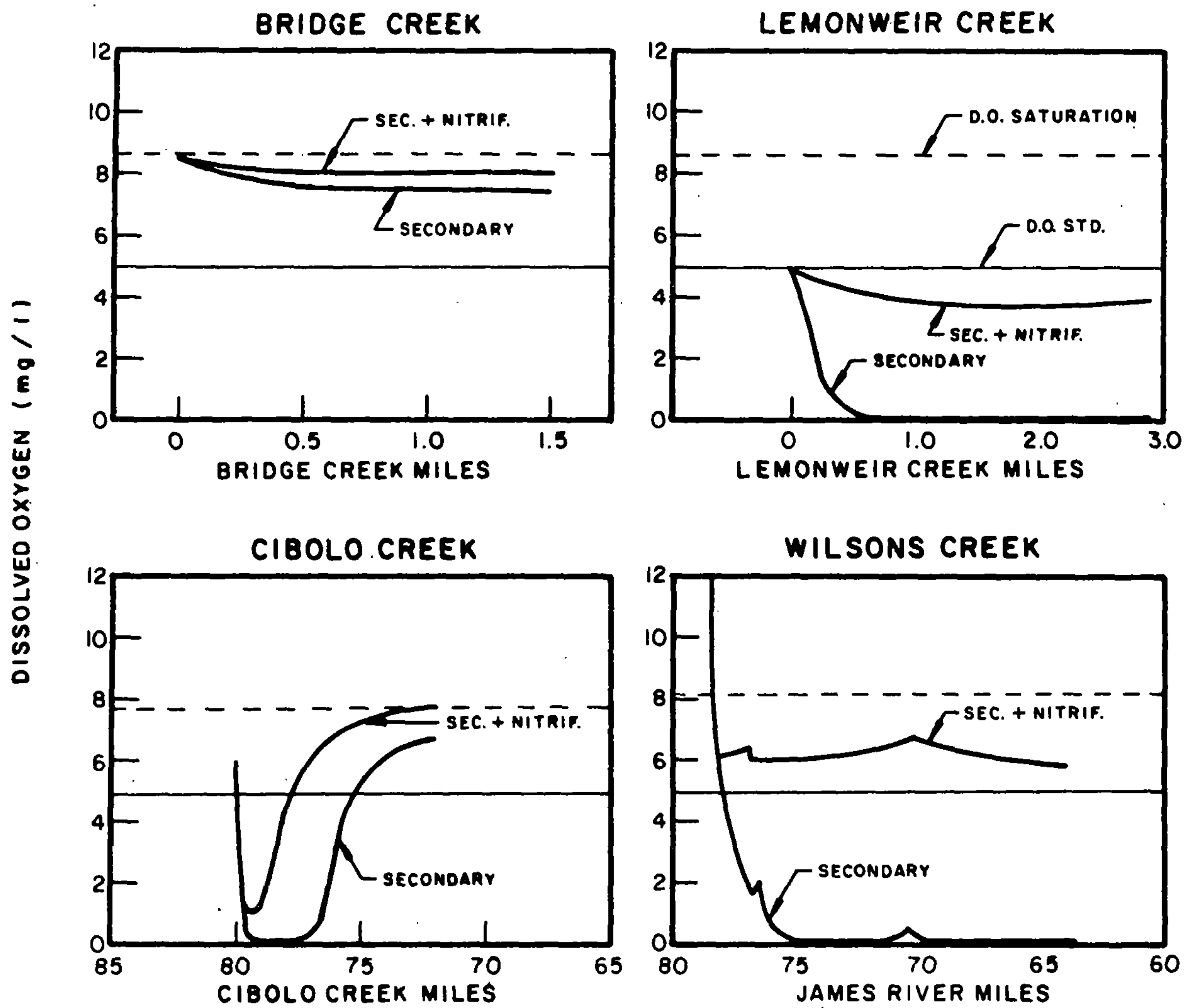


Figure 6.1

Results of Simplified Modeling Analysis



NOTE:
SIMULATIONS AT CRITICAL RIVER FLOW AND TEMPERATURE.

Figure 6.2

Results of Simplified Modeling Analysis

TABLE 6.1

COMPARISON OF SIMPLIFIED MODELING ANALYSIS RESULTS
WITH OTHER WASTELOAD ALLOCATION RESULTS

River	Treatment Required to Meet Standards: Other Wasteload Allocation Analyses[a]	Treatment Required to Meet Standards: Simplified Wasteload Analysis[b]	Similar Decisions Reached in Simplified Wasteload Allocation Versus Other Wasteload Allocation Analyses[b]: For Nitrification
Nashua	Secondary & Nitrification	Secondary & Nitrification	Yes
Patuxent	Secondary & Nitrification	Secondary & Nitrification	Yes
Hurricane	Seconary & Nitrification & Filters	Greater than Secondary & Nitrification[c]	Yes
South	Secondary & Nitrification	Secondary & Nitrification	Yes
Ottawa	Secondary & Nitrification	Greater than Secondary & Nitrification[c]	Yes
Clinton	Secondary & Nitrification & Filters	Secondary & Nitrification	Yes
Bridge	Secondary & Nitrification	Secondary	No
Lemonweir	Secondary & Nitrification	Greater than Secondary & Nitrification[c]	Yes
Cibolo	Secondary & Nitrification & Filters	Greater than Secondary & Nitrification[c]	Yes
Wilsons	Secondary & Nitrification & Filters	Secondary & Nitrification	Yes

[a]Based on dissolved oxygen or ammonia toxicity or other constraints
[b]Based only on results of dissolved oxygen analysis (Figure 6.1, 6.2)
[c]Method indicated treatment in excess of nitrification needed or control of other pollution sources required to meet standards

over expenditure of funds. The first "error" can then be called a water quality (use) error (i.e., quality [use] will be less than projected). The second "error" can be thought of as a facilities error (i.e., the facility is overbuilt to meet target quality [use]). Table 6.1 indicates that the simplified wasteload allocation could have potentially resulted in four water quality errors (Nashua, Clinton, Wilsons Bridge) and two facilities errors (Ottawa, Lemonweir). With respect to nitrification facilities, however, Table 6.1 indicates that the simplified wasteload allocation reached the same decision in 9 of the 10 cases.

In all rivers except Bridge Creek, the simplified dissolved oxygen analyses indicate that secondary treatment will not be adequate to maintain minimum dissolved oxygen levels of 5.0 mg/l at design POTW flows and critical river flows and temperatures. These findings generally confirm the results of other analyses which indicate that a minimum of nitrification is required on all 10 water bodies.

In the Nashua River, Patuxent River, South River, Clinton River, and Wilsons Creek secondary treatment with effluent nitrification is shown by the simplified analysis to provide adequate protection to the dissolved oxygen resources of the rivers. These results agree with other decision making analyses which required secondary treatment with nitrification for the Patuxent and South Rivers but do not agree for the Clinton River, where effluent filtration was installed. Hurricane Creek, Ottawa River, Cibolo Creek, and Lemonweir River are shown to be in violation of dissolved oxygen standards even at secondary treatment and nitrification. This indicates that levels of treatment beyond secondary with nitrification or control of other point or nonpoint pollution sources will be required to maintain dissolved oxygen concentrations above 5.0 mg/l. Detailed modeling studies for Hurricane Creek and Cibolo Creek indicate that secondary treatment with nitrification is not enough to maintain oxygen resources. In Lemonweir Creek, upstream algal nonpoint source problems appear to be the reason why secondary and nitrification is not enough protection for the stream. Detailed analysis for the Ottawa River indicate secondary treatment with effluent nitrification is sufficient to protect oxygen resources.

Overall, the simplified wasteload allocation technique analyses would require similar treatment processes as did other analysis frameworks in 4 of the 10 cases. In two water bodies, treatment in excess of that required by other techniques would be recommended, while in the other four water bodies, the simplified technique would under-estimate treatment requirements.

Caution should be used in making strict quantitative or qualitative interpretations of these results. Where treatment levels in excess of secondary treatment with nitrification are developed by the simplified procedures, the procedure states that this decision must be backed up by further detailed modeling evaluations. Furthermore, in many of the water bodies, actual treatment levels and NPDES limits were developed based on ammonia toxicity analysis or other administrative constraints such as blanket statewide or basinwide policies, which are not taken into consideration in the simplified technique.

Table 6.2 presents comparisons that indicate the simplified wasteload allocation technique recommends similar effluent BOD_5 and ammonia concentrations as those developed by other methods. However, the treatment process units which are recommended by this analysis framework (Table 6.1) may be different than those recommended by other analyses. This difference in part is due to the level of treatment that nitrification and filtration processes can achieve during the critical warm weather periods. In some analyzed cases the original analysts assumed that filtration after nitrification is needed to reduce $CBOD_5$ to below 30.0 mg/l. Recent data (Section 4.0) indicates that operation of the nitrification process during warm weather periods reduces effluent $CBOD_5$ to significantly less than the 30.0 mg/l that was generally assigned in previous analysis. Where this is true it may not be necessary to add filters to treatment facilities to obtain effluent BOD_5 concentrations of between 5.0 and 10.0 mg/l.

In summary, the original analysts made recommendations that a minimum POTW nitrification is necessary in each of the 10 water bodies. Even though analyses

TABLE 6.2

COMPARISON OF EFFLUENT LIMITATIONS

River	Facility	Effluent Requirements for POTW			
		Other Wasteload Allocation Analysis		Simplified Wasteload Allocation Analysis	
		BOD_5 (mg/l)	Ammonia (mg/l)	BOD_5 (mg/l)	Ammonia (mg/l)
Nashua	Fitchburg East.	8.0	1.0	6.5	1.5
Patuxent	Laurel Parkway	10.0	1.0	6.5	1.5
Hurricane	Hurricane	5.0[a]	2.0	Less 6.5	1.5
		2.0[b]	0.8		
South	DuPont	6.7	0.6	6.5	1.5
Ottawa	Lima	-	-	Less 6.5	1.5
	2 Industries	-	-		
Clinton	Aurburn	-	-	6.5	1.5
Bridge	Augusta	30.0	16.0[c]	30.0	20.0[d]
Lemonweir	Tomah	10.0	4.0	Less 6.5	1.5
Cibolo	Odo J. Reidel	5.0	2.0	Less 6.5	1.5
Wilsons	Springfield, S.W.	10.0	1.0	6.5	1.5

[a]Analysis based on pre-operational data
[b]Analysis based on post-operational data
[c]50 percent ammohia removal
[d]Assumed effluent ammonia concentration

constraints were not strictly adhered to, the simplified analytical method confirmed the need for nitrification in 9 of the 10 water bodies that were evaluated. However, for treatment facilities beyond nitrification, the simplified wasteload allocation did not result in a similar decision as that revealed in more detailed analysis in five of nine rivers. For three of the rivers, the simplified wasteload allocation did not indicate a need for additional facilities while the detailed analysis did. This represents a water quality error. In two of the rivers, the simplified wasteload allocation indicated a need for treatment beyond nitrification while the detailed analyses indicated that nitrification should be sufficient. This represents a potential facilities error although as noted above, the procedure for the simplified wasteload allocation stipulates that additional study is necessary if such an analysis indicates that treatment beyond nitrification is needed. In addition, facility errors would have resulted in all five other projects in which filters were constructed if only the simplified analysis had been applied.

6.3 Application of Guidance to Pre- and Post-Improvement Data

The simplified analytical method for secondary and nitrification appears to yield answers regarding treatment requirements similar to answers develped using more detailed decision making processes. For facilities beyond nitrification, the simplified wasteload allocation results in differing conclusions. Direct quantitative assessments of the accuracy of the method are made in this section by using the technique to calculate pre- and post-operational water quality data discussed in Section 2.0 and Appendix C.

Pre- and post-improvement dissolved oxygen profiles were calculated using the simplified analytical method by developing physical and kinetic parameters according to methods suggested by the simplified method. River flows, river temperatures, and waste inputs are all as measured during pre- and post-operational intensive water quality surveys.

Results of dissolved oxygen profiles calculated using a simplified analytical method guidance are compared to measured dissolved concentrations on Figures 6.3 to 6.6. For pre-operational analyses, the simplified method results do not accurately reproduce the entire spatial dissolved oxygen profiles in any of the 10 rivers. The method does approximate the minimum dissolved oxygen at the sag point in 2 of the 10 rivers, Patuxent and Clinton Rivers. In general, the method under-estimates oxygen levels in Hurricane Creek, Ottawa River, Lemonweir Creek, Cibolo Creek, and Wilsons Creek while oxygen concentrations are over-estimated in the South River and Bridge Creek.

Results differ slightly when the simplified analytical method is used to evaluate post-operational dissolved oxygen data (Figures 6.5, 6.6). More favorable comparisons to observed oxygen profiles are obtained for the Patuxent River, South River, Bridge Creek, and Wilsons Creek. The method over predicts concentrations in the Nashua River while it under predicts in Hurricane Creek, Ottawa River, and Cibolo Creek.

A compilation of RMS errors for both sets of analyses are presented on Figure 6.7 for each of the 10 water bodies. Pre-operational RMS errors range from 0.9 to 5.2 mg/l and average 2.4 mg/l. Post-operational errors range from 0.5 to 6.1 mg/l and average 1.9 mg/l. These errors compare with pre- and post-operational analyses developed in Section 4.0 for detailed analyses of 0.67 and 0.94 mg/l, respectively.

Also shown on Figure 6.7 is a comparison of RMS errors calculated for five specific rivers evaluated in the detailed model testing (Section 4.0). In general, the simplified wasteload allocation analysis always yields RMS errors greater than those calculated for the detailed modeling. In pre-operational model testing, detailed models had an RMS error of 0.6 mg/l while the simplified modeling had an RMS error of 2.1 mg/l. Post-operational model testing showed similar results with detailed model RMS errors averaging 1.0 mg/l and simplified models averaging RMS errors of 1.5 mg/l.

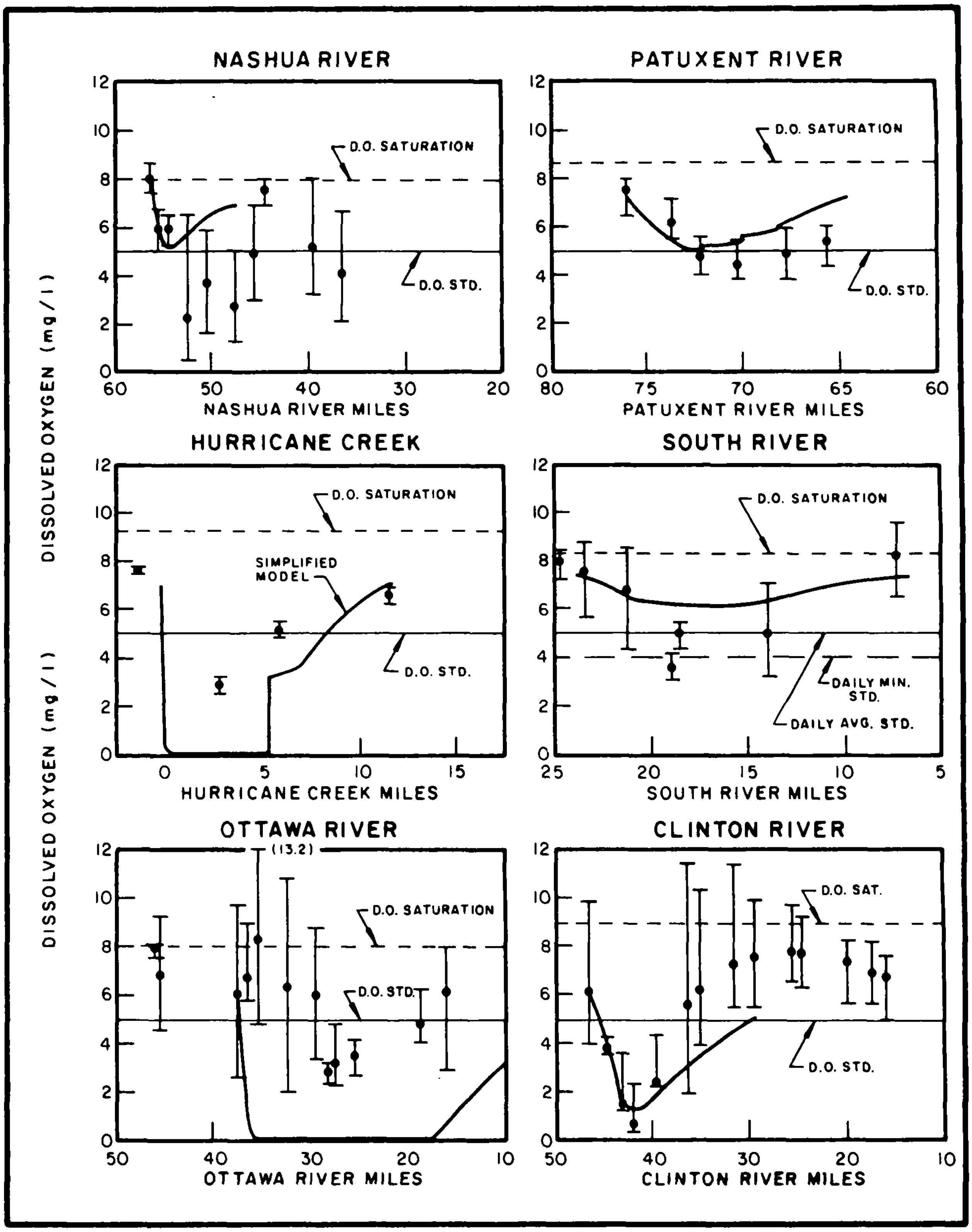


Figure 6.3

Preoperational Testing of Simplified Model

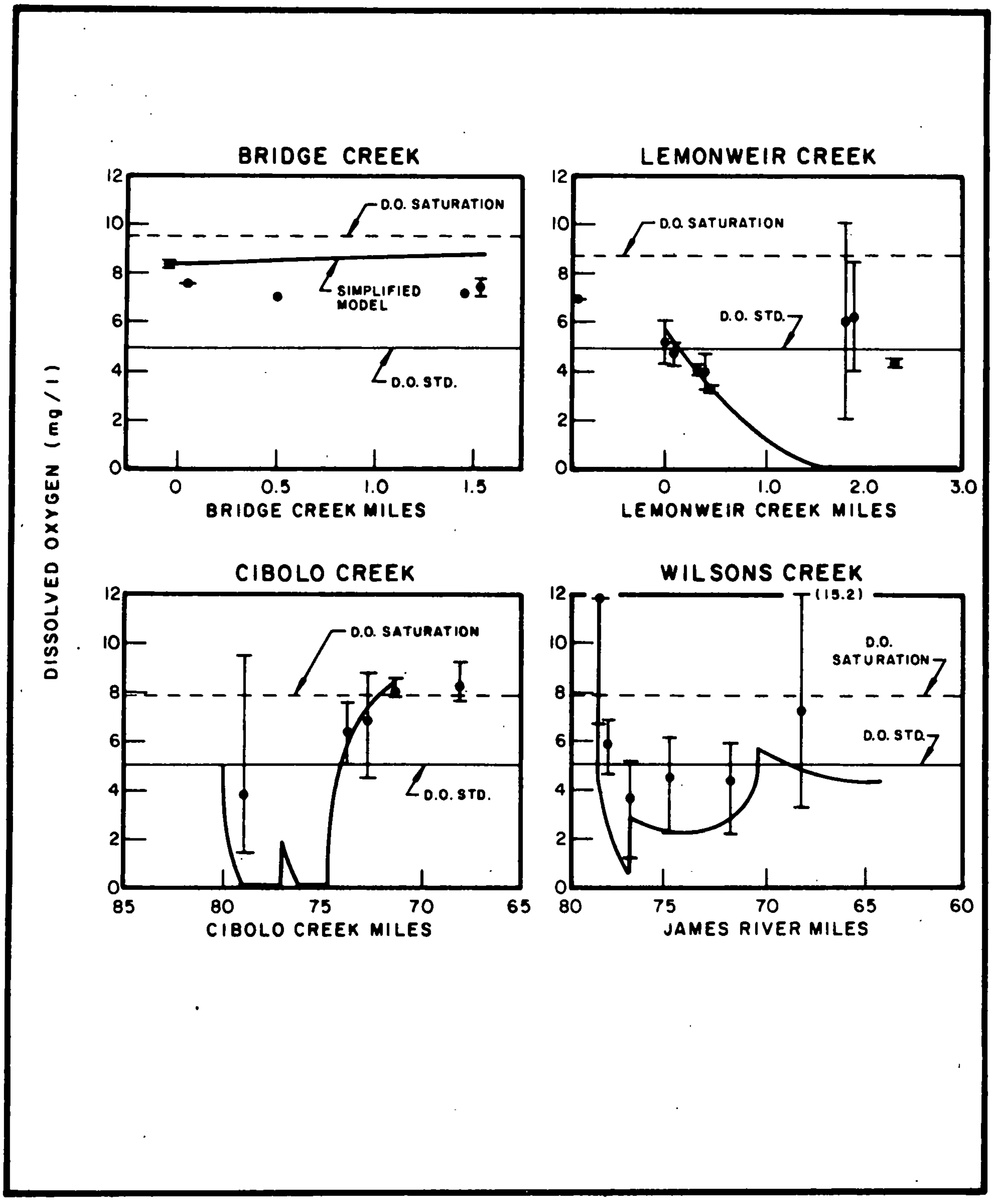


Figure 6.4

Preoperational Testing of Simplified Model

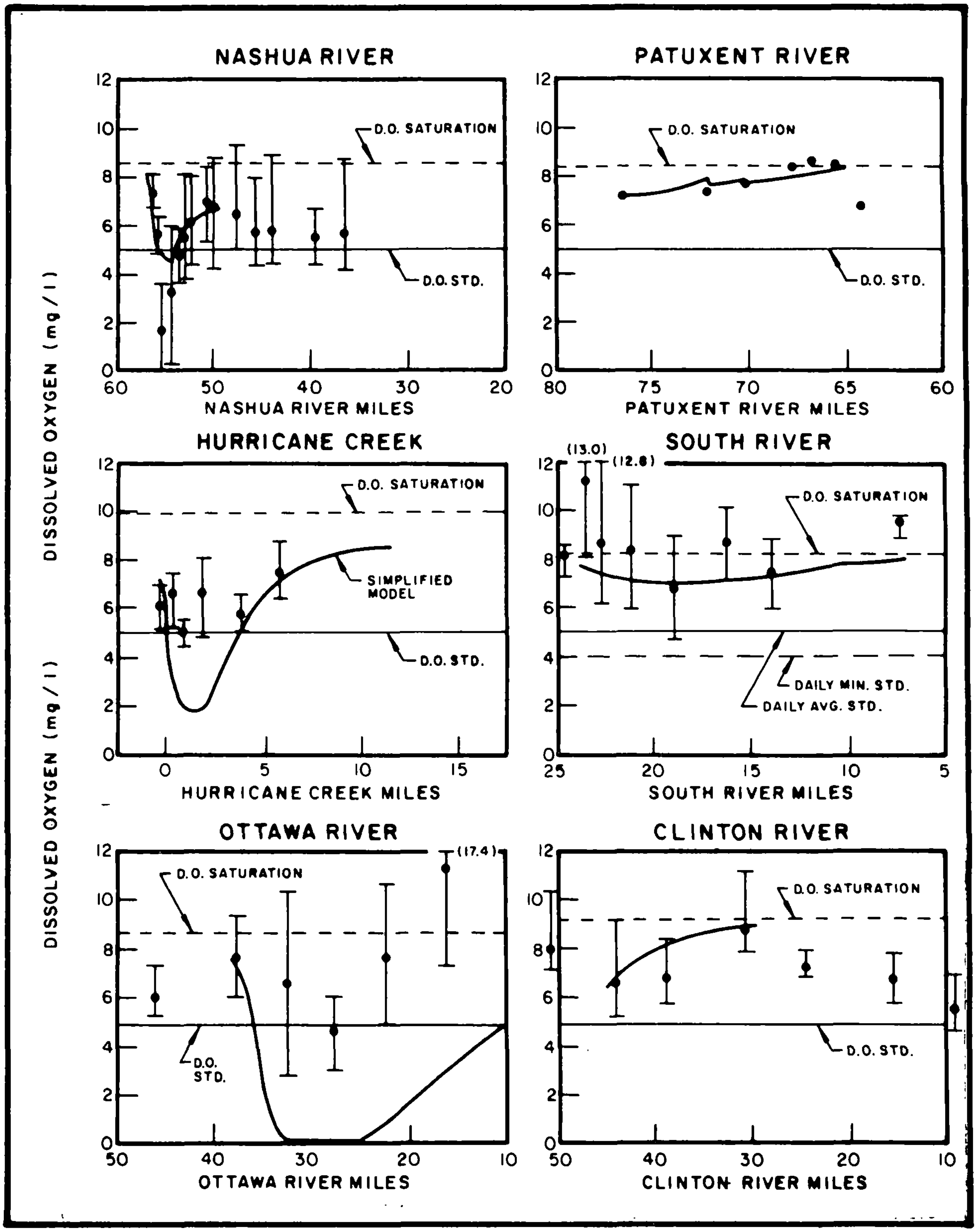


Figure 6.5

Postoperational Testing of Simplified Model

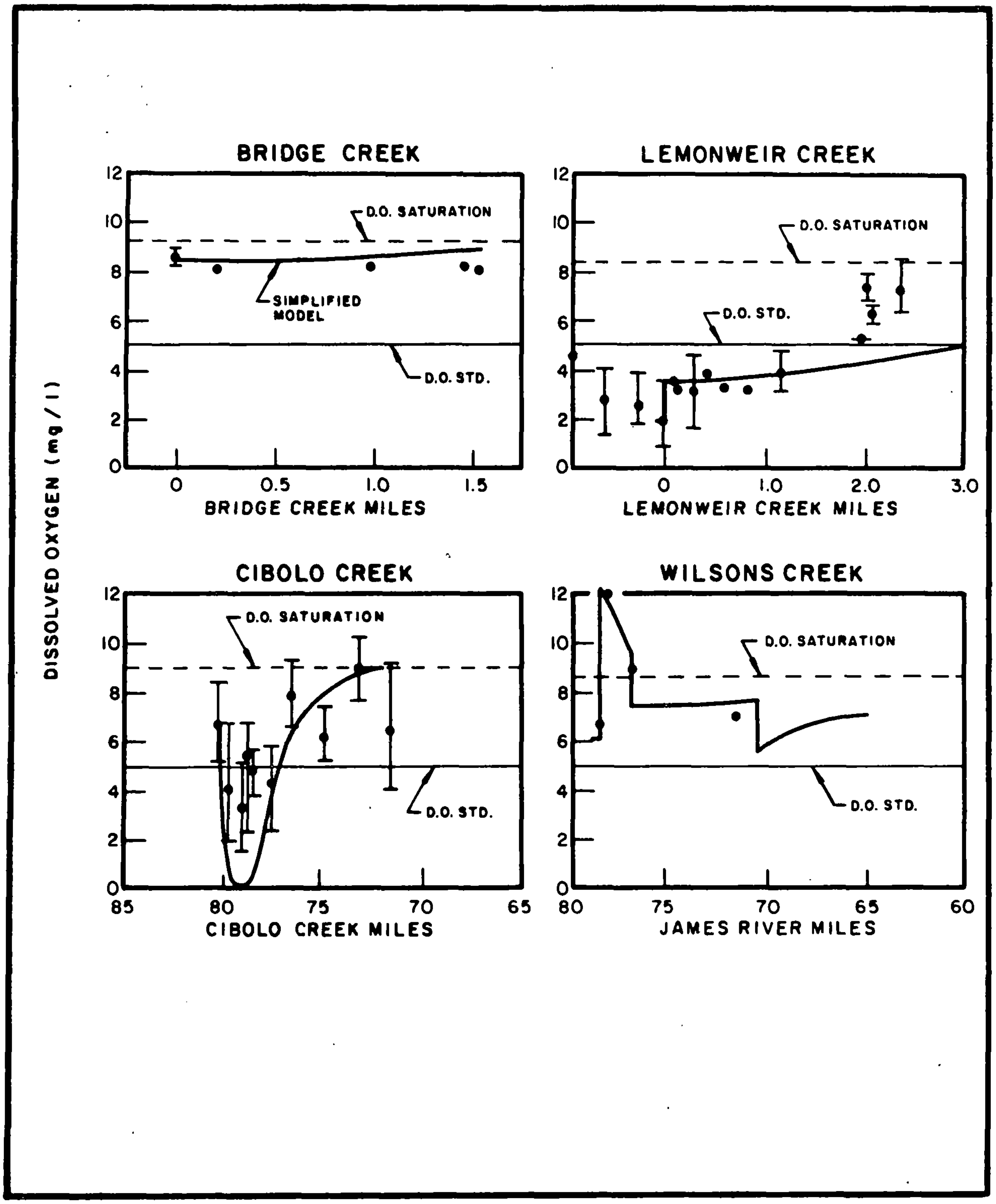


Figure 6.6

Postoperational Testing of Simplified Model

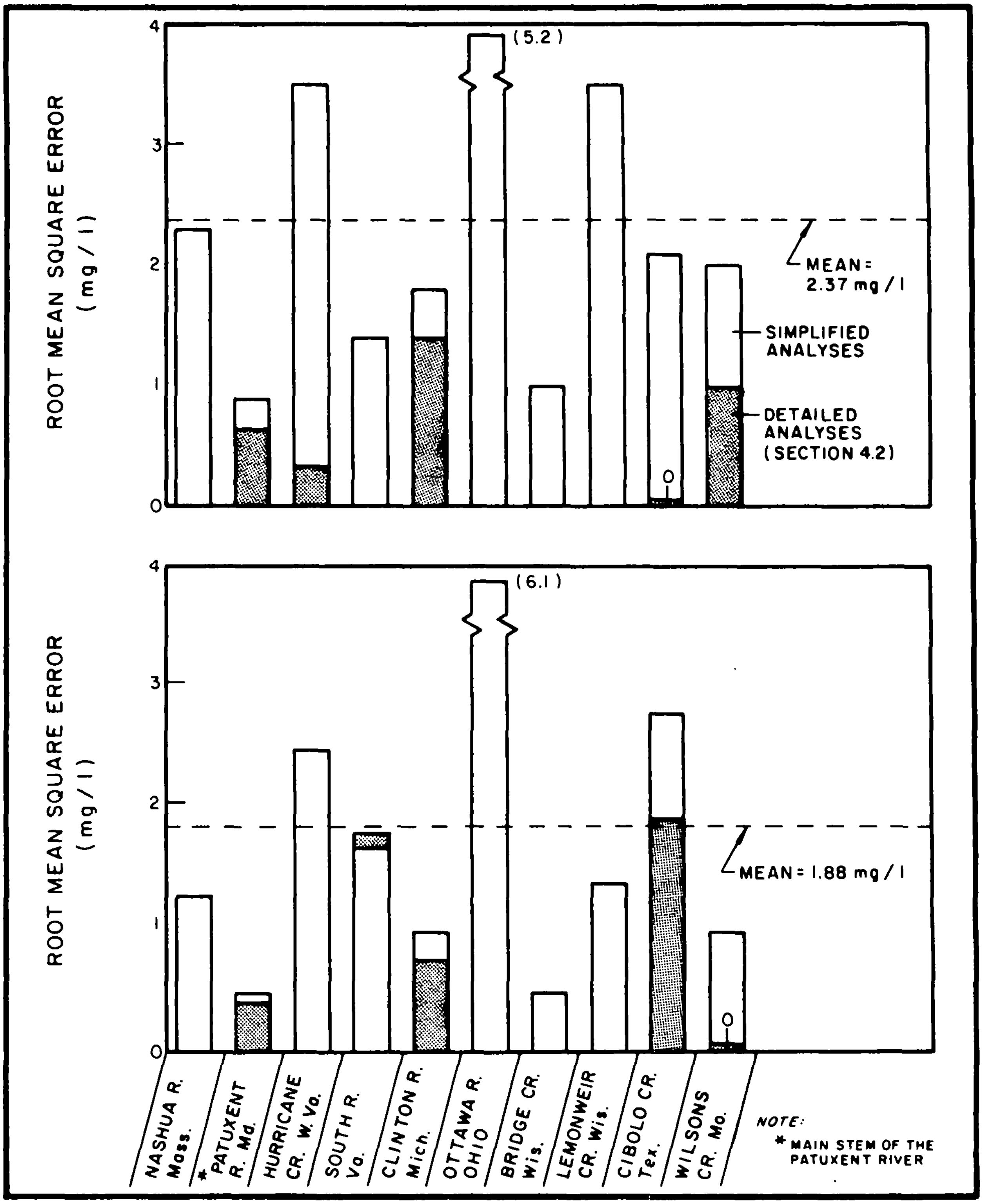


Figure 6.7

Summary of Simplified Method

Regressions of calculated and observed dissolved oxygen concentrations across all 10 water bodies are shown on Figure 6.8. This analysis indicates significant spread of results from the perfect correlation of observed equals calculated for both pre- and post-operational settings. The simple linear regression of calculated dissolved oxygen against observed dissolved oxygen indicates that the simplified method tends to calculate oxygen concentrations which are lower than those which are observed for the pre-operational data sets. The post-operational regression is slightly closer to the calculated equals observed line but still shows a general trend towards predicting dissolved oxygen values that are less than observed data.

As discussed earlier, a number of evaluation criteria are presented in the simplified method which are directed towards limiting the use of the method to single point load free flowing systems. If these criteria are adhered to, only the Patuxent River, Hurricane Creek, South River, Clinton River, Bridge Creek, Cibolo Creek, and Wilsons Creek should be considered in the analyses presented previously. Regression data for only these rivers are shown as open circles on Figure 6.8. Considering only these data, there still appears to be a tendency for the simplified method to yield calculated dissolved oxygen concentrations which are lower than observed data. The RMS errors are slightly reduced to 1.8 and 1.4 mg/l for pre- and post-operational data when only these seven water bodies are included in the analysis.

Insight as to why the simplified technique did not accurately reproduce field data can be obtained by comparing the reaction rates developed by simplified analytical method procedures and by other calibration and validation procedures (Tables 6.3 and 6.4). Considering only those single point source streams, Tables 6.3 and 6.4 shows that the simplified method BOD decay rates are on the order of 50 to 100 percent higher than those developed through traditional modeling techniques. Therefore, the rates used in this method appear to over estimate dissolved oxygen impacts.

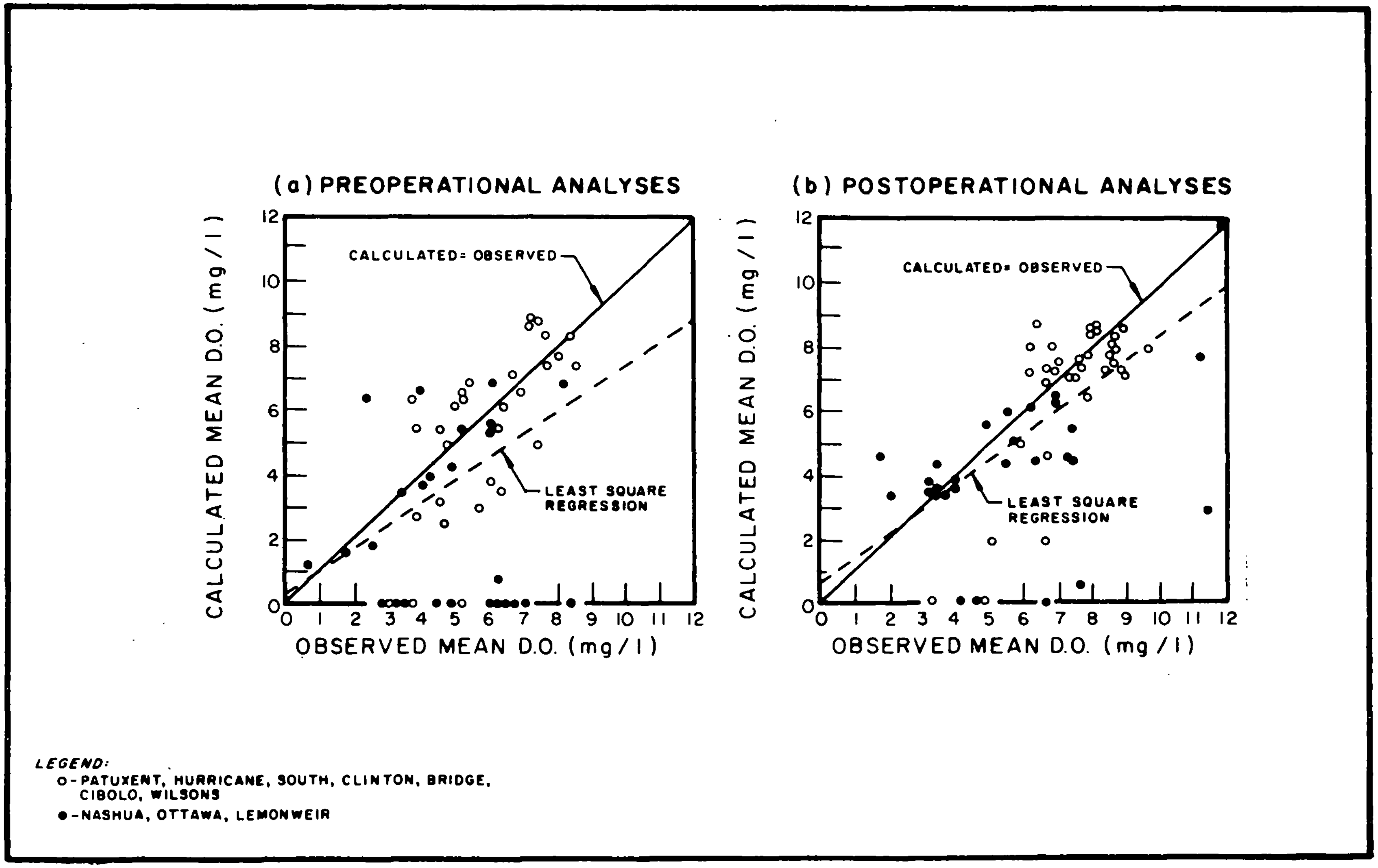


Figure 6.8

Regression of Calculated and Observed Dissolved Oxygen Concentrations

TABLE 6.3

COMPARISON OF MODEL REACTION RATES

River	BOD Decay Rate[a]				NBOD Decay Rate[a]			
	Pre-operational		Post-operational		Pre-operational		Post-operational	
	1[b]	2[c]	1[b]	2[c]	1[b]	2[c]	1[b]	2[c]
Nashua	NA	-	0.4 - 2.3	0.48 - 0.65	NA	-	0.9 - 2.0	0.40
Patuxent	0.37 - 0.50	0.57	0.37 - 0.50	0.60	0.17 - 0.43	0.40	0.17 - 0.43	0.40
Hurricane	0.1 - 0.5	0.49	0.35	0.49	0.1 - 0.5	0.30	0.70[d]	0.40
South	0.3 - 0.60	.41 - .81	0.3 - 0.60	.41 - .81	1.6 - 2.0	.40	1.6 - 2.0	.40
Clinton	2.2	0.79	0.20	0.77	NA	0.40	2.5 - 3.8	.40
Ottawa	NA	0.56	NA	0.57	NA	0.40	NA	0.4
Bridge	NA	0.49	NA	0.49	NA	0.40	NA	0.40
Lemonweir	NA	0.62	NA	0.62	NA	0.40	NA	0.40
Cibolo	0.18	.35 - 0.51	0.18	0.37 - 0.4	0.25	0.30	0.25	0.30
Wilsons	0.30	0.61 - .84	0.30	0.4	0.40	0.29 - 0.59	0.40	0.40

[a](1/day at 20°C base e)

[b]Original modeling studies

[c]Rates as per "simplified analytical method"

[d]0.7 for NH_3, 0.2 for organic -N hydrolysis

TABLE 6.4

COMPARISON OF MODEL REACTION RATES

River	Reaeration Rate[a]			
	Pre-operational		Post-operational	
	1[b]	2[c]	1[b]	2[c]
Nashua	NA	-	0.8 - 19	9. - 24.
Patuxent	1.7 - 4.2	3. - 4.	1.7 - 4.2	3.4
Hurricane	0.6 - 2.5	0.37	0.41	0.37
South	2.1 - 6.8	4.5 - 5.3	2.1 - 6.8	3.7 - 5.3
Clinton	-	7.5	-	6.5
Ottawa	NA	1.47	NA	1.47
Bridge	NA	12.5	NA	12.5
Lemonweir	NA	1.4	NA	1.4
Cibolo	0.5 - 5.1	0.3 - 1.3	0.49 - 2.4	0.5 - 1.1
Wilsons	0.6 - 4.5	2.7 - 15.1	0.47 - 5.2	4.3 - 18.1

[a] (1/day at 20°C base e)
[b] Original modeling studies
[c] Rates as per "simplified analytical method"

Simplified technique nitrification rates are generally on the order of 0.4/day while calibration rates ranged from 0.25 to about 3.8. In Lemonweir Creek and the Ottawa River where models were not utilized or were unavailable, water quality data do not indicate the presence of active nitrification. However, use of the analytical technique without examination of these data would still lead the analyst to select a nitrification rate in the order of 0.4/day.

Reaeration rates suggested by the simplified technique were about equal to those selected by calibration analyses. One exception was in the Nashua River, an impounded river, which would not qualify as being a free flowing stream and would be excluded by the evaluation criteria. Other rates differed between simplified and detailed analyses but do not show a definite trend.

The simplified analytical technique dissolved oxygen analyses indicated that treatment levels beyond secondary treatment were required in 9 of the 10 rivers evaluated. This decision was consistent with other dissolved oxygen and ammonia toxicity analyses which indicated a minimum of secondary plus inplant nitrification was required in all 10 rivers.

Quantitative error evaluations, however, indicate the simplified technique, when applied to free flowing single point source rivers, yielded RMS errors of 1.8 and 1.4 mg/l for pre- and post-operational evaluations. The general tendency was for the simplified technique to calculate dissolved oxygen concentrations lower than those observed.

The CBOD decay rates that developed following simplified procedures, were higher than those developed by more resource intensive calibration analyses. In addition, calibrated NBOD decay rates ranged from 0.2/day to in excess of 2.0/day while simplified procedure rates were near 0.4/day. In two rivers where water quality data did not strongly indicate the occurrence of nitrification, the simplified procedure would yield an NBOD decay rate of about 0.4/day.

One reason why the simplified modeling technique performs fairly well in the decision making phase of analysis but has substantial quantitative RMS errors when compared to field dissolved oxygen data, is related to the effluent ultimate oxygen demand assigned to various levels of treatment. The simplified modeling technique assigns a total effluent oxygen demand of about 140.0 mg/l (30.0 mg/l $CBOD_5$ X 1.5 and about 20.0 mg/l NH_3 X 4.57) to secondary treatment. Secondary treatment with nitrification, is assigned a total effluent oxygen demand of about 21.0 mg/l (6.5 mg/l $CBOD_5$ X 2.5 and 1.2 mg/l NH_3 X 4.57). This difference in total effluent oxygen demanding loading rate illustrates the significant pollutant reductions that can be achieved with a nitrification process. It also reduces the point pollutant impacts on river oxygen levels, thereby, reducing the importance of accurately estimating CBOD and NBOD oxidation rates.

At summer critical conditions the technique tends to yield proper decisions as to allowable waste loadings; however, calculated expected dissolved oxygen concentrations may be vastly different from observed oxygen levels. Because of the RMS errors calculated, it may not be advisable to use the modeling technique to extrapolate to seasonal treatment levels. When performing seasonal wasteload allocation analysis, smaller differences in POTW ultimate oxygen demands than the difference between 140.0 mg/l (secondary treatment) and 21.0 mg/l (secondary plus nitrification) are being examined. Based on the quantitative analyses, the simplified technique does not appear to be accurate enough to make realistic predictions needed when performing seasonal wasteload allocations involving relatively small differences in pollutant concentrations from various treatment levels.

As a result of this comparison between the simplified wasteload allocation and the more detailed water quality analysis, it is concluded that:

a. the simplified wasteload allocation adequately reproduces the decision on facilities up to secondary plus nitrification;

b. beyond secondary plus nitrification, the simplified wasteload allocation results in different facilities decisions in at least three of the nine cases;

c. quantitatively the simplified wasteload allocation performs poorly in comparison to observed dissolved oxygen data with RMS errors that are 50 to about 200 percent higher than that resulting from the more resource intensive water quality analysis, and;

d. the simplified method is not appropriate for determining seasonal wasteload allocations unless additional site specific data are collected.

SECTION 7.0

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APPENDIX A

PERSONNEL POINTS OF CONTACT

State	Agency	Contact
Arizona	Department of Health Services Bureau of Water Quality Control	Dean Moss Dave Woodruff
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Connecticut	Department of Environmental Protection	Mike Curtis Ron Waghorn
Delaware	-	Jay Brahmbhatt Paul Jones
Florida	Department of Pollution Control	Jay Thadaraj Dean Jackman
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Illinois	Illinois Environmental Protection Agency	Ken Rogers Jim Park
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New York	New York State Health Department	Carl Simpson
	Department of Environmental Conservation Regional Office	John Midelkop
	Rensselaer County Plant	George Lehner
	Albany County Plants	Frank McGowan
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Texas	Department of Water Resources	Dale White Dave Buzan
Vermont	Department of Water Resources	Dave Clough
Virginia	State Water Control Board	Dale Phillips Gary Moore
	State Water Control Board - Piedmont Regional Office	Tom Modena
	Occoquan Water Shed Monitoring Laboratory	Tom Grizzard
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	Delaware Valley Regional Planning Commission	Ken Miller
	Tennessee Valley Authority	John Higgins
	Trinity River Authority of Texas	Tom Sanders Dr. Richard Browning

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APPENDIX C

CASE SUMMARIES

Note:

1. References are not provided in the text of the following case studies. Information sources reviewed are presented by state in Appendix B.

2. The information provided does not represent an exhaustive study of the particular water body. It does represent an overview of the project which was limited by finite time and budgetary constraints.

3. The project review stops at the time of the post-operational survey. Further changes or improvements in stream water quality are therefore, not covered in the case summaries.

APPENDIX C

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Project Case Study
Water Body: Nashua River, Massachusetts

The Nashua River, located in northern central Massachusetts and southern New Hampshire, is a major tributary to the Merrimack River. The Nashua consists of a north branch, south branch and main stem and receives wastewater inputs from numerous municipalities and industries. The north branch of the river which receives waste inputs from the cities of Fitchburg and Leominster is the area of concern for this review.

In 1973, a water quality sampling study of the Nashua was conducted to collect water chemistry and other data required for a wasteload allocation modeling analysis (Figure C-1). These data showed low dissolved oxygen concentrations, and elevated BOD_5 and ammonia-N levels. At the time of this survey, a number of industries plus the cities of Fitchburg and Leominster were discharging treated secondary effluents to the north branch.

Around 1975 two new treatment plants, Fitchburg Westerly and Fitchburg Easterly, came on line. These plants were designed based on the 1973 wasteload allocation analysis to provide secondary treatment, air nitrification, phosphorus removal, and carbon adsorption (Westerly only). However, carbon adsorption columns have not functioned properly since the construction of the new Westerly POTW.

A review of the AWT application by USEPA for the city of Leominster indicated the original wasteload allocation modeling analysis contained uncertainty which made the AWT recommendation questionable. To overcome this, the state of Massachusetts conducted another water quality survey of the Nashua in 1977. This survey conducted at a slightly lower river flow, indicated some slight improvements in North Branch oxygen, BOD_5 and ammonia levels, presumably in response to increased treatment levels at Fitchburg. Although, Fitchburg Westerly was not meeting its designed effluent BOD_5 of 8.0 mg/l and Leominster was not upgraded to AWT, dramatic improvements in oxygen levels were not observed (Figure C-2).

Results of macroinvertebrate data showed stressed river conditions in 1973 with a predominance of pollution tolerant species such as tubified worms, leeches and midge larve. More recent data indicated no significant shift to clean water communities.

Recent recreational changes noted was the use of scenic portions of the lower river for canoeing. In recent years the river has been upgraded from class C (warm water fishery, secondary contact recreation) to class B (warm water fishery, primary and secondary contact recreation). In addition, the state has already reclaimed a 40 mile by 300 foot wide "greenland buffer strip" for the purpose of scenic recreation and to prevent location of any further sources of pollution near the river. Although these changes are being made before significant improvements in water quality are observed, the changes are part of the areawide planning program and are being made in anticipation of improved water quality in response to AWT/AST at the major point discharges.

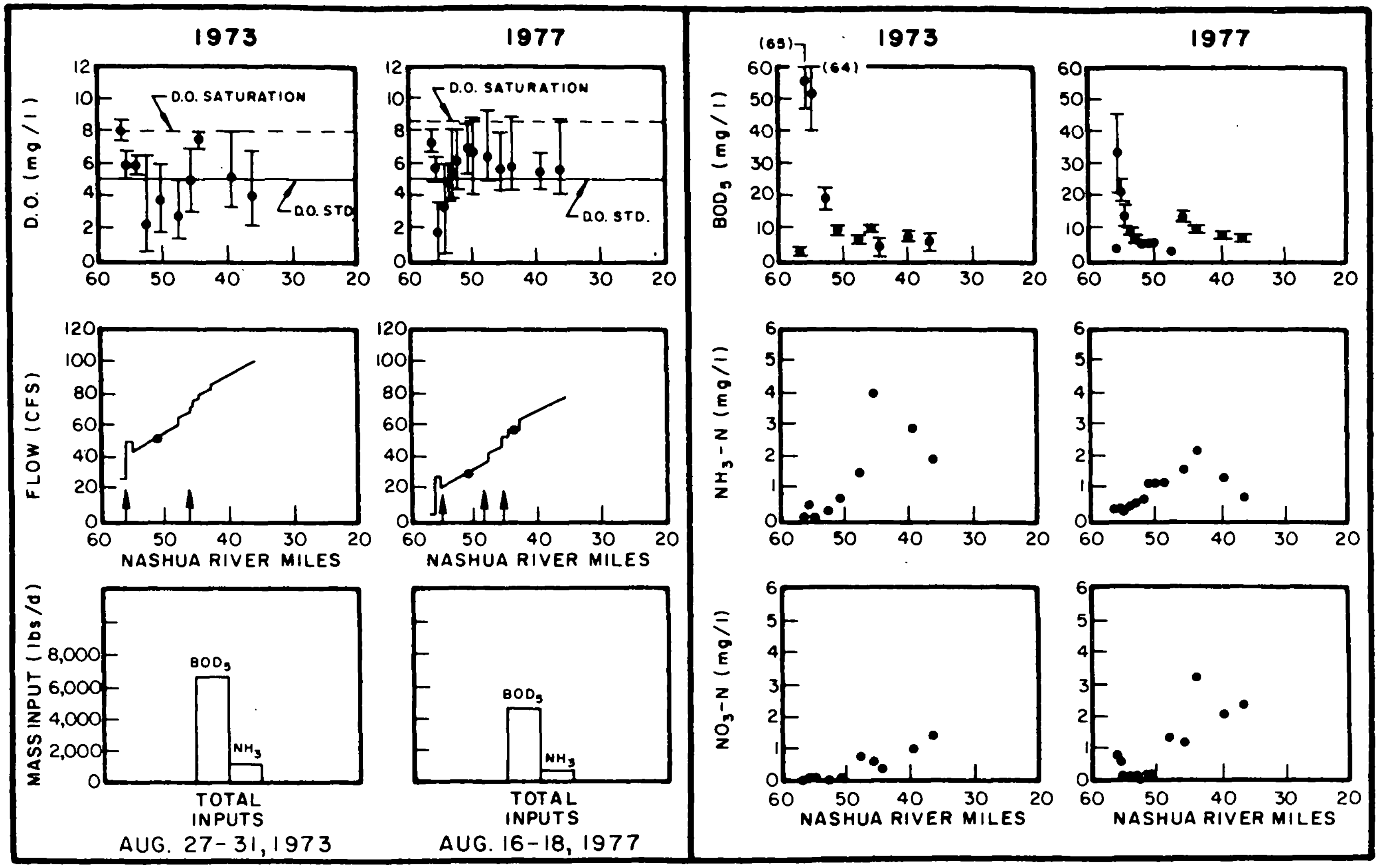


Figure C-1

Water Quality Comparisons for Nashua River, Massachusetts (Secondary Treatment to Secondary Treatment + Nitrification + P-Removal)

Figure C-2

POST AUDIT FACT SHEET

NO. 1 WATER BODY NAME:	STREAM / RIVER / LAKE / ESTUARY	TRIBUTARY TO:	STATE:	MODEL USED TO MAKE WLA:
Nashua River (North Branch)	RIVER X	Merrimack River	Massachusetts	YES X NO

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

- AVERAGE DEPTH:[2] 1 to 4 feet
- APPROX. VELOCITY:[2] .1 to .5 ft/sec
- SLOPE:[4] 15 ft/mile (impounded throughout)
- 7Q10 FLOW:[3] 3.8 cfs

	BEFORE			AFTER				
POINT SOURCE DESIGN:	Multiple Inputs[1]	Leominster POTW	TOTAL	Fitchburg East.	Fitchburg West.	Leominster	TOTAL	% CHANGE
FLOW (MGD) =		6.0		12.4	15.3	6.0		
BOD_5 (mg/l) / (lbs/d) =				8	8			
NH_3 (mg/l) / (lbs/d) =				1	1			
COMMENT:								
POINT SOURCE OPERATING:			TOTAL				TOTAL	% CHANGE
FLOW (MGD) =	10.5	6.4	16.9	4.5	12.5	3.9	20.9	+ 24%
BOD_5 (mg/l) / (lbs/d) =	59/(5175)	23/(1235)	6410	4.3/ (160)	35/ (3500)	24.0/ (780)	4540	- 29%
NH_3 (mg/l) / (lbs/d) =	3.2/(279)	10.3/(548)	827	.28/ (11)	.43/ (45)	18.0/ (585)	641	- 22%
COMMENT:	Sec.Treat.	Act.Sludge		See Note 5		Act.Sludge		
RIVER CHEMISTRY:								
AVERAGE D.O. (mg/l) =		5.1			5.5			+ 8%
MINIMUM D.O. (mg/l) =		0.6			0.2			- 67%
MAXIMUM BOD_5 (mg/l) =		65.0			45.0			- 31%
MAXIMUM NH_3 (mg/l) =		4.0			2.4			- 40%
MAX. UNIONIZED NH_3 (mg/l) =		0.031			0.009			- 71%

COMMENTS: 1. Crocker Mill, Fitchburg Paper, Simonds Saw & Steel, Fitchburg POTW; 2. At 7Q10; 3. Upstream of point source inputs; 4. There are dams on the North Branch; 5. Act. Sludge + Air nitrification + P-removal, also carbon columns which do not work at the west plant at the time of this study.

Project Case Study
Water Body: Blackstone River, Rhode Island

The Blackstone River located in north eastern Rhode Island has its headwaters near the city of Blackstone, Massachusetts. The major point source load to the river, is the Woonsocket POTW and is located about 12 miles upstream from the mouth of the river.

Before upgrading, in late 1977, the Woonsocket POTW was a primary treatment plant. Water quality data collected in 1977 (Figure C-3) showed minimum river dissolved oxygen concentrations of 2.0 mg/l downstream of the POTW inflow. Instream BOD_5 concentrations during this survey were as high as 8.0 mg/l while maximum ammonia concentrations were near 0.5 mg/l.

In 1977, the Woonsocket POTW was expanded and upgraded to an activated sludge type secondary treatment plant (Figure C-4). Post-operational field sampling data collected in the Blackstone River showed improved dissolved oxygen concentrations after the plant upgrade. After the plant was brought on line, minimum dissolved oxygen concentrations were about 7.2 mg/l as opposed to near 1.0 mg/l before plant upgrading (Figure C-5).

No water quality modeling was done to develop wasteload allocations because the POTW by federal law was required to upgrade to a minimum of secondary treatment. Further, recreational data and/or biological data were not uncovered within the framework of this project.

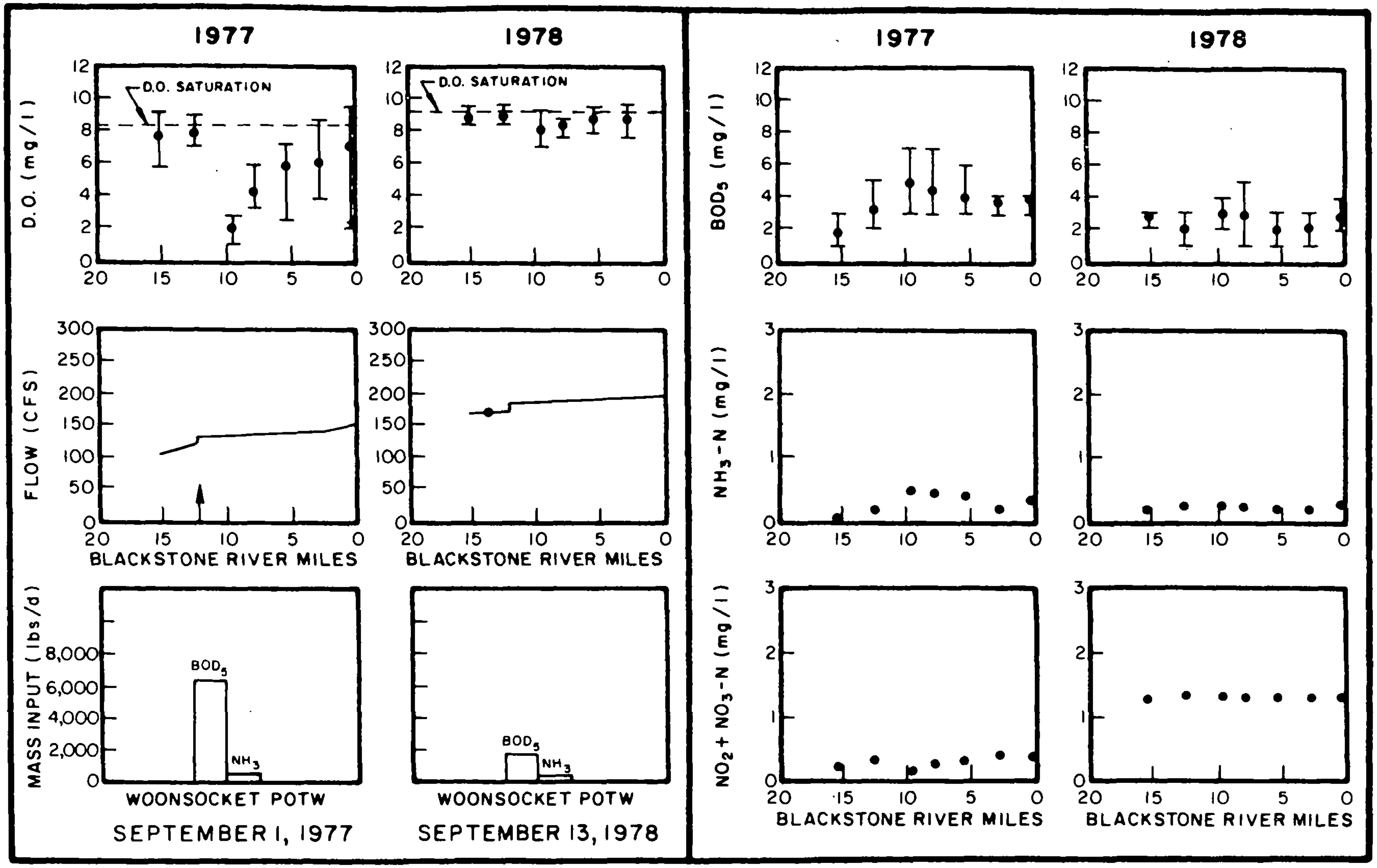


Figure C-3

Water Quality Comparions for Blackstone River, Rhode Island
(Primary Treatment to Secondary Treatment)

Figure C-4

POST AUDIT FACT SHEET

NO. 2 WATER BODY NAME: Blackstone River	STREAM RIVER X LAKE ESTUARY	TRIBUTARY TO: Atlantic Ocean	STATE: Rhode Island	MODEL USED TO MAKE WLA: YES ___ NO X

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH= approximately 6 feet

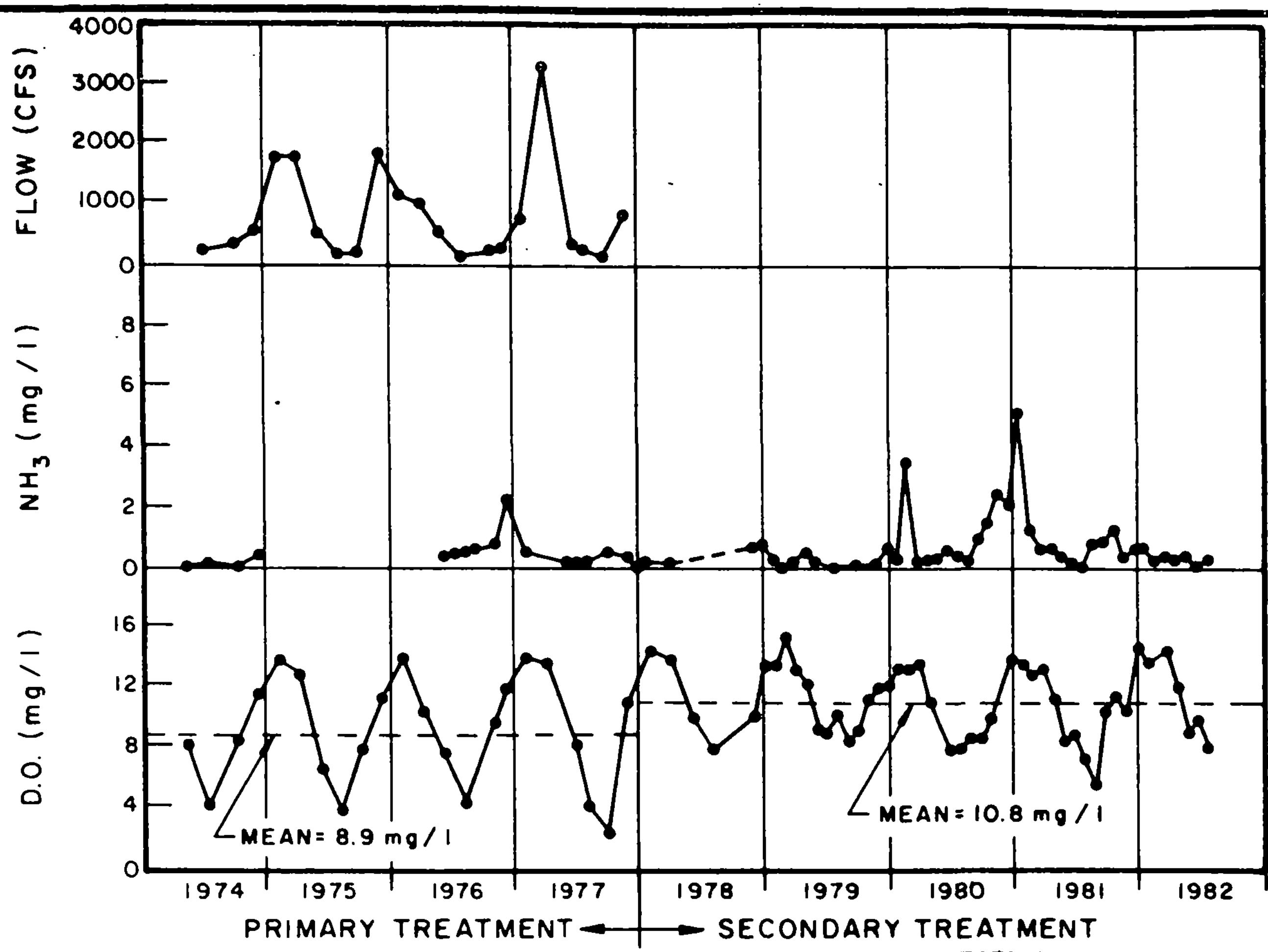
APPROX. VELOCITY= variable

SLOPE= impounded

7Q10 FLOW= 101 cfs upstream of POTW

	BEFORE			AFTER			
POINT SOURCE DESIGN:		Woonsocket POTW	TOTAL		Woonsocket POTW	TOTAL	% CHANGE
FLOW (MGD) =							
BOD_5 (mg/l) / (lbs/d)=							
NH_3 (mg/l) / (lbs/d)=							
COMMENT:							
POINT SOURCE OPERATING:			TOTAL			TOTAL	% CHANGE
FLOW (MGD)=		6.5	6.5		8.5	8.5	+ 31%
BOD_5 (mg/l) / (lbs/d)=		116/(6288)	6228		23/(1630)	1630	- 74%
NH_3 (mg/l) / (lbs/d)=		7.5/(407)	407		3.0/(213)	213	- 48%
COMMENT:	Primary Treatment			Secondary Treatment			
RIVER CHEMISTRY:							
AVERAGE D.O. (mg/l)=		5.9			8.7		+ 48%
MINIMUM D.O. (mg/l)=		1.0			7.2		+ 620%
MAXIMUM BOD_5 (mg/l)=		7.0			5.0		- 29%
MAXIMUM NH_3 (mg/l)=		0.48			0.28		- 42%
MAX. UNIONIZED NH_3 (mg/l)=		0.002			0.001		- 50%

COMMENTS:



JUNE, JULY, AUGUST & SEPTEMBER

	MEAN (mg/l)			STANDARD DEVIATION (mg/l)	
	BEFORE	AFTER	% CHANGE	BEFORE	AFTER
FLOW[1]	225	—	——	103	—
D.O.	5.3	8.3	+57 %	2.4	1.2
NH_3	0.29	0.41	+41 %	0.17	0.33

1-UNITS = CFS

DATA SOURCE STORET

Figure C-5

Time History Data Analysis for Blackstone River

(Station Code: 01112900 · Agency Code: 112WRD)

Project Case Study
Water Body: Hudson River, New York

The area of interest for this evaluation is the upper Hudson River estuary in the vicinity of Albany, New York. At the upper end of the study area, near river mile 154, is the Troy Dam. Downstream the river is tidal but free of sea water intrusion. Major sources of municipal and industrial waste are discharged to the river upstream of the Troy Dam and in the vicinity of Albany.

In the late 1960s and early 1970s the river, upstream and downstream of the dam, received large amounts of treated and untreated municipal and industrial wastewater. In the mid-1970s, many industrial discharges in the Albany area were diverted to the three major new POTWs; Albany North, Albany South and Rensselaer.

Before upgrading, the treatment plants were designed as primary facilities and after upgrading, the plant designs were for activated sludge secondary treatment. Post-audit data from 1977 show the two Albany area plants are achieving effluent BOD_5 levels of less than 10.0 mg/l and effluent ammonia levels of less than 1.0 mg/l.

The following figures (C-6, C-7), show that, although, point BOD_5 loads have been reduced by about 94 percent between 1964 and 1977, the BOD_5 load entering the upper river from the Troy Dam has remained high and has actually increased by some 42 percent. At the high flow condition observed in 1977, these upstream loads now dominate the point loads by a factor in excess of 20 to 1. At 7Q10 this factor may be reduced to about 7 to 1. Between the two available surveys, the total BOD_5 load has been reduced by about 28 percent.

It is evident from the figures that after upgrading of the treatment plants, the river dissolved oxygen levels have increased substantially while BOD_5 and ammonia in the river have decreased slightly. Dissolved oxygen concentrations during 1977 were well above the dissolved oxygen standard of 4.0 mg/l.

In the mid- and late 1960s water quality mathematical model wasteload allocation studies were performed to develop waste treatment efficiencies required to meet river dissolved oxygen standards. These studies required at least secondary treatment plus 50 percent ammonia removal at all Albany area inputs and other loads upstream of the Troy Dam (Figure C-8).

Evaluation of the post-audit data set using observed river flows and wasteload allocation model kinetic rates indicates (Figure C-8) that the model agrees fairly well with the observed data. To actually simulate the observed BOD_5 and dissolved oxygen data, however, it was necessary to reduce the CBOD decay rate (K_d) from a rate of 0.25/day (base e, 20^o C) to about 0.15/day (see main text, Section 4.3).

No information was available within the framework of this project concerning biological improvements and/or improved recreational uses of the river associated with upgraded water quality and improved treatment. Since completion of the project, however, two new riverside parks with boat launching facilities have been built in this area of the Hudson.

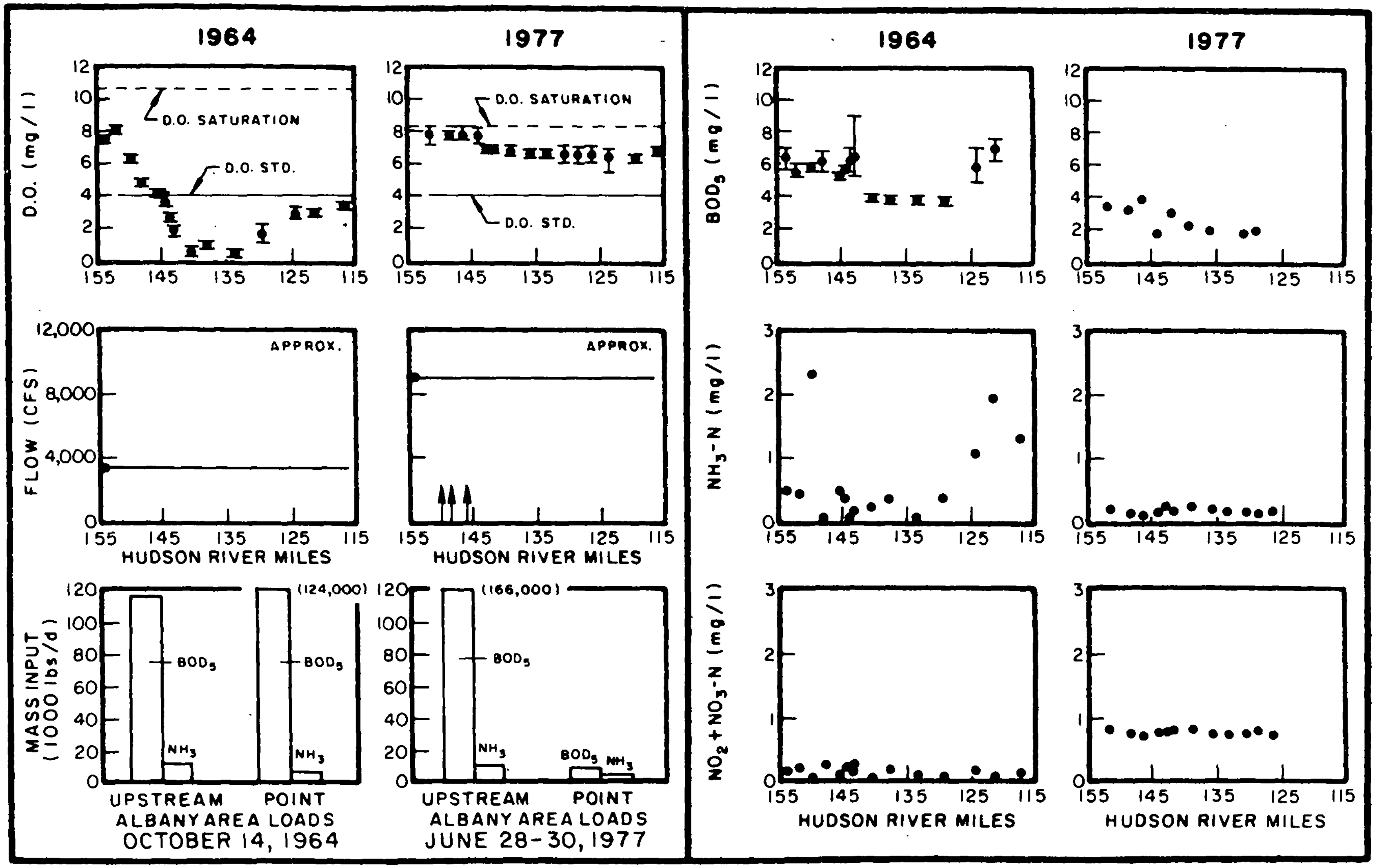


Figure C-6

Water Quality Comparisons for Hudson River, New York
(Primary Treatment to Secondary Treatment)

Figure C-7

POST AUDIT FACT SHEET

NO. 3 WATER BODY NAME: Hudson River	STREAM / RIVER / LAKE / ESTUARY X	TRIBUTARY TO: Atlantic Ocean	STATE: New York	MODEL USED TO MAKE WLA: YES X NO

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH= approximately 20 ft

APPROX. VELOCITY= fresh water approximately 0.1 cfs

SLOPE= N/A

7Q10 FLOW= approximately 3,000 cfs

	BEFORE			AFTER			
POINT SOURCE DESIGN:			TOTAL	Albany No.	Albany So.	TOTAL	% CHANGE
FLOW (MGD) =							
BOD_5 (mg/l) / (lbs/d)=							
NH_3 (mg/l) / (lbs/d)=							
COMMENT:							
POINT SOURCE OPERATING:			TOTAL			TOTAL[1]	% CHANGE
FLOW (MGD)=			-	15.0	19.5	-	
BOD_5 (mg/l) / (lbs/d)=			-/(124000)	8/(1087)	8.5/(1386)	-/(7411)	- 94%
NH_3 (mg/l) / (lbs/d)=			-/(5000)	.1/(12.5)	.1/(16.2)	-/(1890)	- 62%
COMMENT:			Raw, PRI & Industrial	Sec.Treat.	Sec.Treat.		
RIVER CHEMISTRY:							
AVERAGE D.O. (mg/l)=		3.9			7.0		- 79%
MINIMUM D.O. (mg/l)=		0.4			5.6		+ 1300%
MAXIMUM BOD_5 (mg/l)=		9.0			4.0		- 55%
MAXIMUM NH_3 (mg/l)=		2.3			0.25		- 89%
MAX. UNIONIZED NH_3 (mg/l)=		0.005			0.003		- 40%

COMMENTS: 1. Does not include any industrial loadings;

POST AUDIT MODEL FACT SHEET

WATER BODY NAME: HUDSON RIVER, NEW YORK

MODEL TYPE: FINITE SEGMENT **CALIBRATED:** YES X NO ___

MODEL NAME: HRM (HUDSON RIVER MOD.) **VALIDATED:** YES X NO ___

WASTE LOAD ALLOCATION

RIVER FLOW: 5100 CFS

RIVER TEMP.: 25°C

POINT SOURCE INFO:

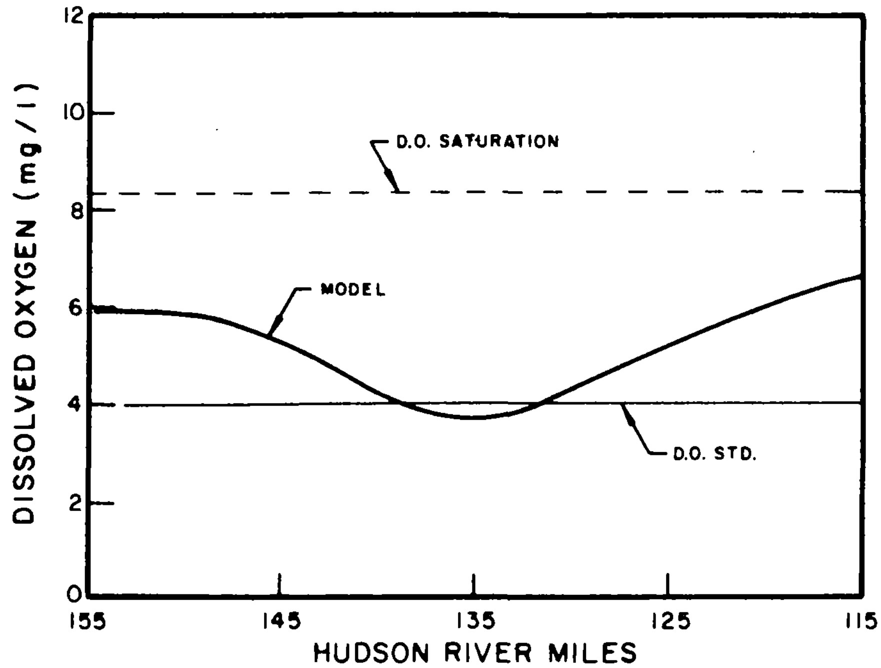
	TOTAL LOAD
Q (MGD) =	—
BOD_5 (lbs/day) =	47,000
NBOD (lbs/day) =	62,000

UPSTREAM INFO:

Q (CFS) =	5,100
BOD_5 (mg/l) =	1.8
NBOD (mg/l) =	2.3

COMMENTS:

FOR 80% BOD_5 & 40% NBOD REMOVAL



POST AUDIT

RIVER FLOW: 8790 CFS

RIVER TEMP.: 24.3°C

POINT SOURCE INFO:

	TOTAL LOAD
Q (MGD) =	51.7
BOD_5 (lbs/day) =	7,411
NBOD (lbs/day) =	8,640

UPSTREAM INFO:

Q (CFS) =	8,790
BOD_5 (mg/l) =	3.5
NBOD (mg/l) =	0.2

COMMENTS:

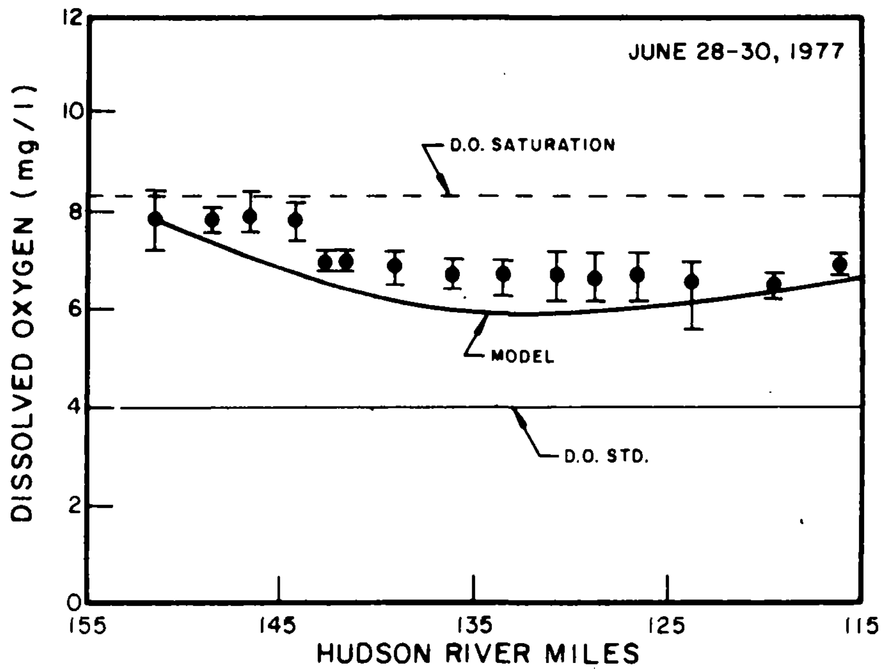


Figure C-8

Project Case Study
Water Body: Main Stem Patuxent River, Maryland

The Patuxent River located in the state of Maryland is tributary to Chesapeake Bay on the western shore of the bay. The river is formed just east of Washington, D.C. and flows south east towards Chesapeake Bay. Upstream the river has three branches; Upper Main Stem, Middle Patuxent and Little Patuxent. The area of interest for this review is the Upper Main Stem from about river mile 75 to river mile 65.

In this reach, the Laurel Parkway POTW contributes about 6 cfs of flow to the river. At a 7Q10 flow of 16 cfs, this sewage accounts for about 27 percent of the river flow. The river is approximately 1.9 feet deep and flows at a velocity of near 0.3 ft/sec. at low flow.

In 1968, when the Laurel Parkway POTW was designed and operated as a secondary treatment plant, intensive water quality data collected in 1968 (Figures C-9, C-10), showed dissolved oxygen concentrations in violation of both the daily average standard (5.0 mg/l) and the minimum daily standard (4.0 mg/l). These data also indicate that instream conversion of ammonia-N to nitrate nitrogen was in part responsible for the dissolved oxygen depressions.

Additional dissolved oxygen data (Figure C-11) available at river mile 70.8 during 1966 and 1967 showed the river was stressed during each of the low flow summer months. Both 1966 and 1977 data collected at flows at/or less than the 7Q10 low flow exhibited dissolved oxygen concentrations between 2.9 and 4.8 mg/l.

Because river quality was already stressed and growth was anticipated in the basin, plans were developed to upgrade the treatment at the Laurel Parkway and Maryland City POTWs (mile 78.5) as well as POTWs on other branches of the free flowing river. In 1969, the state legislature passed rulings requiring all treatment plants in the basin to be designed for AWT. This policy was further defined by the State of Maryland Department of Health and Mental Hygiene, which defined effluent limits as 10.0 mg/l BOD_5 and 3.0 mg/l total nitrogen (oxidizable nitrogen of 1.0 mg/l).

Recently, treatment requirements have been re-evaluated and permits revised to be less stringent. The Parkway plant now has a permit of 30.0 mg/l BOD_5 and 6.0 mg/l of TKN, while the Maryland City has limits of only BOD_5 at 30.0 mg/l. These revisions were made after original projections were made and after this present study was complete.

A water quality model calibration and projection analysis conducted by USEPA, Region III and published in 1974, confirmed that effluent limits of 10.0 mg/l BOD and total nitrogen of 3.0 mg/l (oxidizable nitrogen of 1.0 mg/l) would allow for compliance with the dissolved oxygen standard of 5.0 mg/l in the Upper Main Stem. The modeling framework called AUTO-QUAL was used in this analysis. The 1968 data was used for model calibration and additional 1973 data was used for model verification.

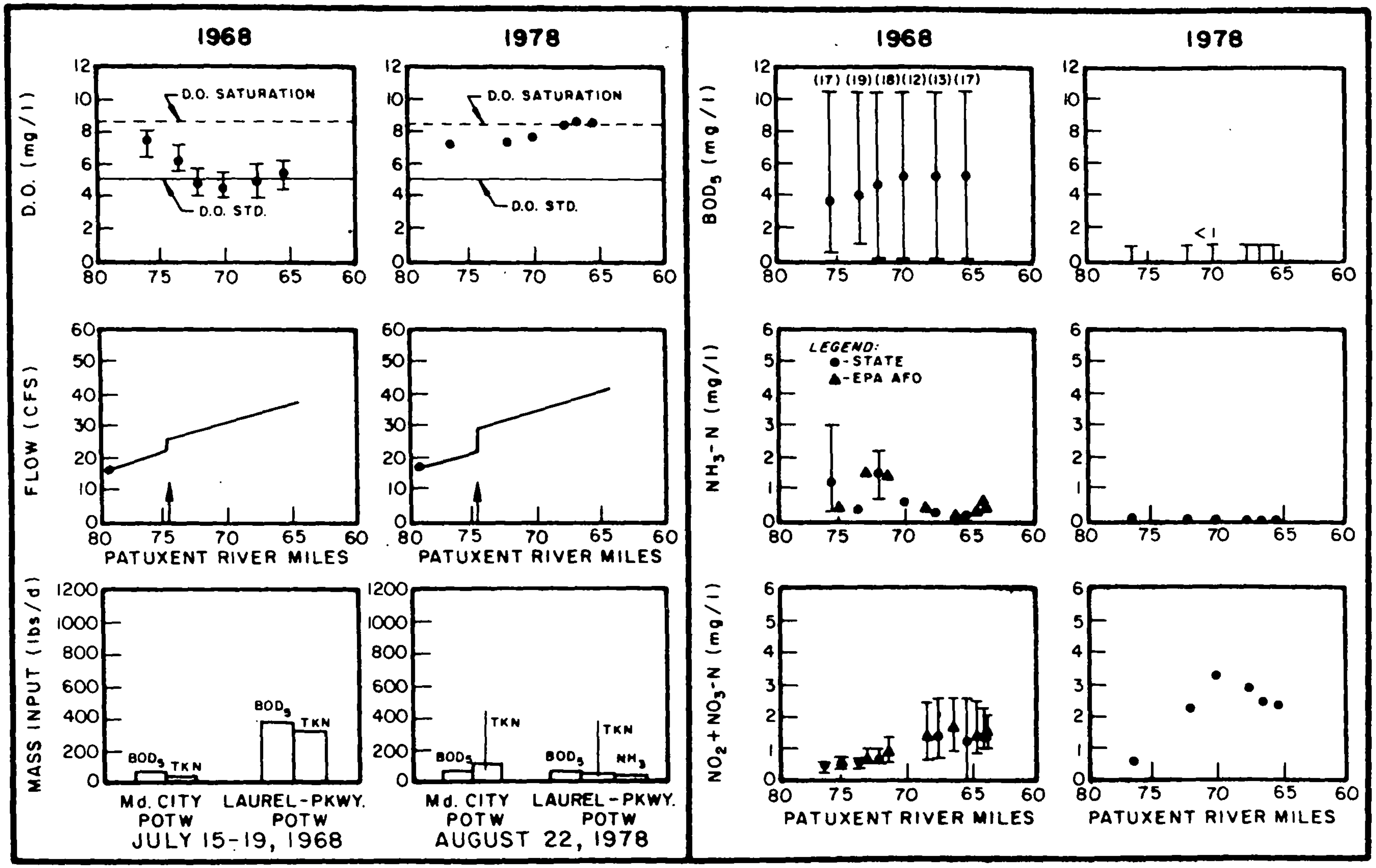


Figure C-9

Water Quality Comparisons for Main Stem Patuxent River, Maryland
(Secondary Treatment to Secondary + Nitrification)

Figure C-10

POST AUDIT FACT SHEET

NO. 4 WATER BODY NAME: Main Stem Patuxent River	STREAM / RIVER / LAKE / ESTUARY: X	TRIBUTARY TO: Chesapeake Bay	STATE: Maryland	MODEL USED TO MAKE WLA: YES X NO

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH= 1-2 feet at 7Q10

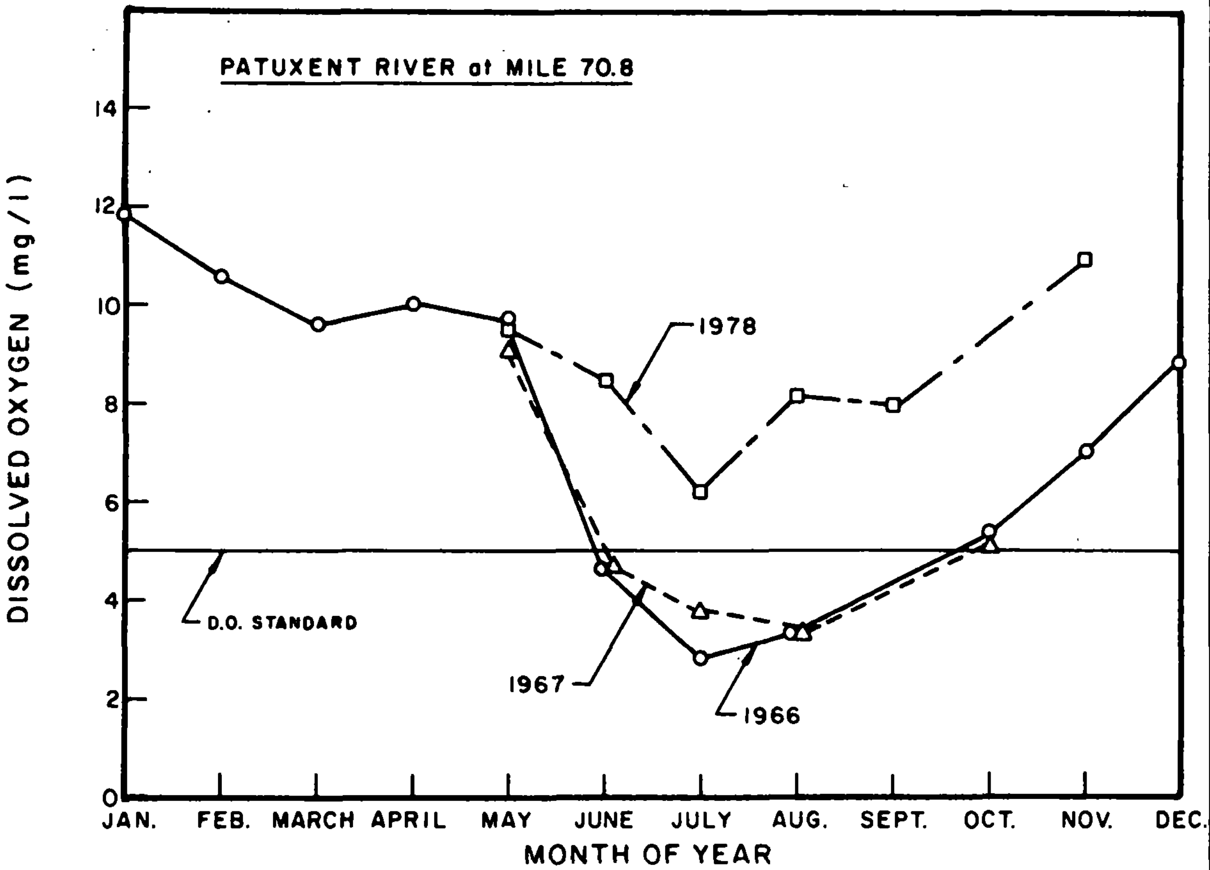
APPROX. VELOCITY= 0.3 ft/sec at 7Q10

SLOPE= N/A

7Q10 FLOW= 16.5 cfs upstream of point sources

	BEFORE			AFTER			
POINT SOURCE DESIGN:	Laurel Pkwy. POTW	MD Cty POTW	TOTAL	Laurel Pkwy. POTW	MD Cty POTW	TOTAL	% CHANGE
FLOW (MGD) =	2.4	0.75		8.2[1]	1.7[1]		
BOD_5 (mg/l) / (lbs/d)=				10/(684)	10/(142)		
NH_3 (mg/l) / (lbs/d)=				3/(205)[2]	3/(25)[2]		
COMMENT:	Secondary						
POINT SOURCE OPERATING:			TOTAL			TOTAL	% CHANGE
FLOW (MGD)=	2.0	.44	2.4	4.5	.48	5.0	+ 108%
BOD_5 (mg/l) / (lbs/d)=	21/(350)	10/(37)	387	1/(38)	10/(40)	78	- 80%
NH_3 (mg/l) / (lbs/d)=	17/(283)	3.5/(13)[3]	296	.3/(11)[3]	15/(60)	71.0	- 76%
COMMENT:	Sec.Treat.	Sec.Treat.		Nitrif.	Sec.Treat.		
RIVER CHEMISTRY:							
AVERAGE D.O. (mg/l)=		5.5			7.9		+ 44%
MINIMUM D.O. (mg/l)=		3.8			7.6		+ 100%
MAXIMUM BOD_5 (mg/l)=		18			<1.0		- 94%
MAXIMUM NH_3 (mg/l)=		2.2			0.1		- 95%
MAX. UNIONIZED NH_3 (mg/l)=		0.014			0.0005		- 96%

COMMENTS: 1. For year 1988 (Pkwy.), 1980 (MD Cty) as per 1975 permits; 2. Total nitrogen; 3. TKN



JUNE, JULY, AUGUST & SEPTEMBER

	MEAN (mg/l)		
	BEFORE	AFTER	% CHANGE
D.O.	3.7	7.6	+ 108%

Figure C-11

Time History Data Analysis for Main Stem Patuxent River
(Station: PXT0708-State of Maryland)

In mid-1974 the Laurel Parkway POTW construction was completed and the plant came on line as with secondary treatment plus inplant nitrification (not denitrification). Instream water quality data collected August 22, 1978 (Figure C-9), show substantial increases in river oxygen concentrations and decreases in BOD_5 and ammonia concentrations in response to the improved treatment levels. Further, data collected at other times during 1978 also indicated significant improvements in river oxygen levels near the sag point (river mile 70.3). These data collected at flows near 7Q10 indicate average 1978 summer dissolved oxygen concentrations of about 7.6 mg/l in comparison to average 1966, 1967 concentrations of about 3.7 mg/l.

In order to assess the adequacy of the verified model to predict changes in water quality, the model coefficients k_d, k_n, k_a, etc. used in the low flow wasteload allocation model were input to a post-audit simulation model at proper flows and temperatures. The wasteloads from Maryland City and Laurel Parkway POTWs were also input to the model which was set up for August 22, 1978 conditions. Dissolved oxygen simulations made are shown on the bottom of Figure 12. As can be seen on this figure, the verified model coefficients were able to simulate post-audit field data with a high degree of accuracy.

Within the framework of this project, no biological sampling data or recreational data were available to evaluate changes in river use in response to upgraded treatment.

POST AUDIT MODEL FACT SHEET

WATER BODY NAME: MAIN STEM PATUXENT RIVER

MODEL TYPE: FINITE DIFFERENCE MODEL

CALIBRATED: YES X NO ___

MODEL NAME: AUTO SS OR AUTO QUAL

VALIDATED: YES X NO ___

WASTE LOAD ALLOCATION

RIVER FLOW: 16.5 CFS

RIVER TEMP: 28°C

POINT SOURCE INFO:

	LAUREL PARKWAY	Md. CITY
Q (MGD) =	6.4	2.7
BOD_5 (mg/l) =	10	10
NH_3 (mg/l) =	1	1

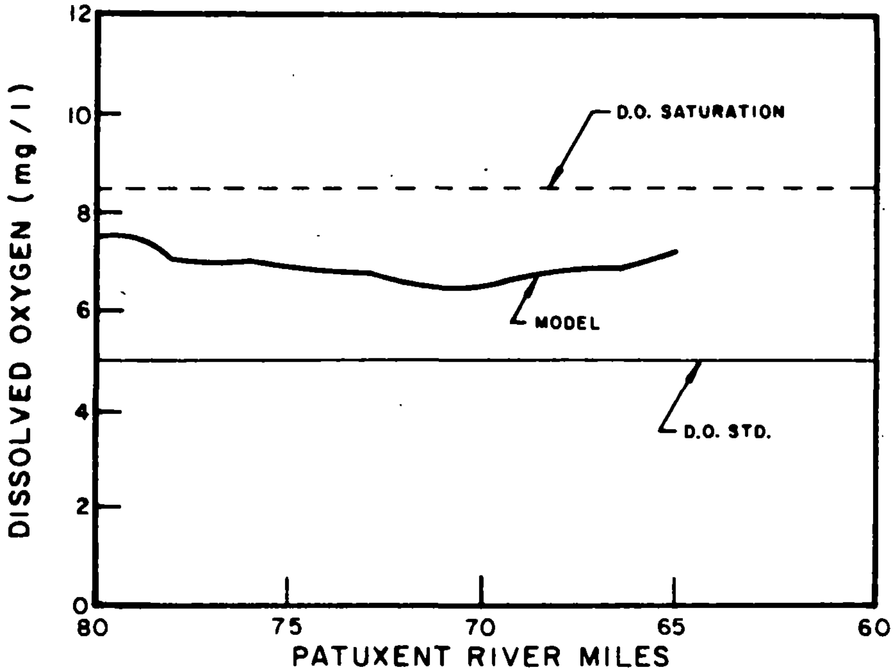
UPSTREAM INFO:

Q (CFS) = 16.5

BOD_5 (mg/l) = 1.4

NH_3 (mg/l) = 0.6

COMMENTS:



POST AUDIT

RIVER FLOW:[1] 17.6 CFS

RIVER TEMP: 23°C

POINT SOURCE INFO:

	LAUREL PARKWAY	Md. CITY
Q (MGD) =	4.5	.48
BOD_5 (mg/l) =	1.0	9.6
NH_3 (mg/l) =	0.3	12.5

UPSTREAM INFO:

Q (CFS) = 17.6

BOD_5 (mg/l) = 1.0

NH_3 (mg/l) = 0.6

COMMENTS:

1 - UPSTREAM OF POINT SOURCES

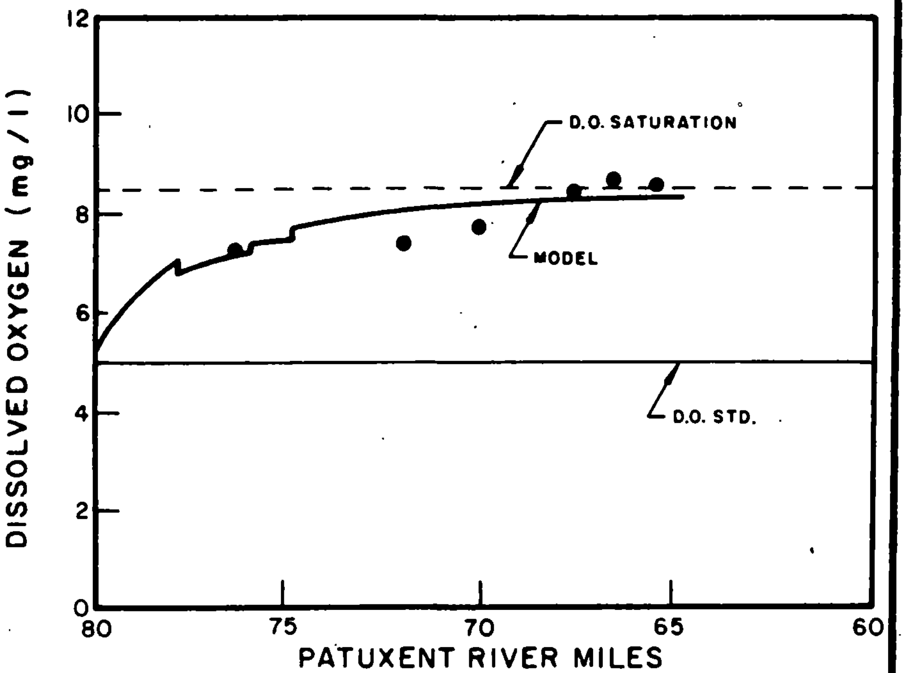


Figure C-12

Project Case Study
Water Body: Hurricane Creek, West Virginia

Hurricane Creek located in western West Virginia flows north from the city of Hurricane towards the Kanawha River. The creek is a shallow slow moving creek which at a 7Q10 low flow of 0.1 cfs is effluent dominated by the Hurricane POTW effluent flow of about 0.5 mgd.

The Hurricane treatment facility in 1972 was a trickling filter plant with an effluent BOD_5 concentration in excess of 70.0 mg/l. Water quality data collected in the creek in June 1972 (Figures C-13, C-14) show the river to be stressed with respect to dissolved oxygen, BOD_5 and TKN levels. A water quality model developed by USEPA, Region III in 1975 and calibrated against the 1972 water quality data showed the Hurricane POTW to be the major source of pollution in Hurricane Creek. A wasteload allocation performed using this model (Figure C-15) showed treatment at the Hurrican POTW would have to be upgraded to effluent BOD_5 and TKN concentration of 5.0 and 2.0 mg/l, respectively in order to comply with a river dissolved oxygen standard of 5.0 mg/l.

In the late 1970s an oxidation ditch treatment facility was constructed and the old trickling filter plant was abandoned. In 1981, intensive water quality data was collected in Hurricane Creek to evaluate the effectiveness of the new treatment levels. At the time of this survey, the Hurricane POTW was actively nitrifying in the plant. Data collected during the 1981 survey (Figure C-13) showed increases in creek dissolved oxygen concentrations as well as decreases in both BOD_5 and TKN when results were compared to 1971 field data. During this survey, which was conducted at stream flows near the 7Q10 of 0.10 cfs, average oxygen concentrations did not violate the daily average dissolved oxygen standard of 5.0 mg/l.

As part of the present study, the calibrated model was applied using the post-audit survey conditions to evaluate the effectiveness of the model. This analysis was performed using the September 11, 1981 creek flows, temperatures, the Hurricane POTW September 11, 1981 effluent characteristic BOD_5, and TKN equaling 4.7 and 1.4 mg/l, respectively. All oxidation and reaeration rates were as set equal to the rate used in the original wasteload allocation. The results of this analysis are shown on Figure C-15.

As indicated on this figure the model does predict oxygen concentrations which are increased from the earlier calibration period. The model, however, does over calculate instream dissolved oxygen concentrations.

In the framework of the present study, no data were found on biological changes or recreational activity on Hurricane Creek.

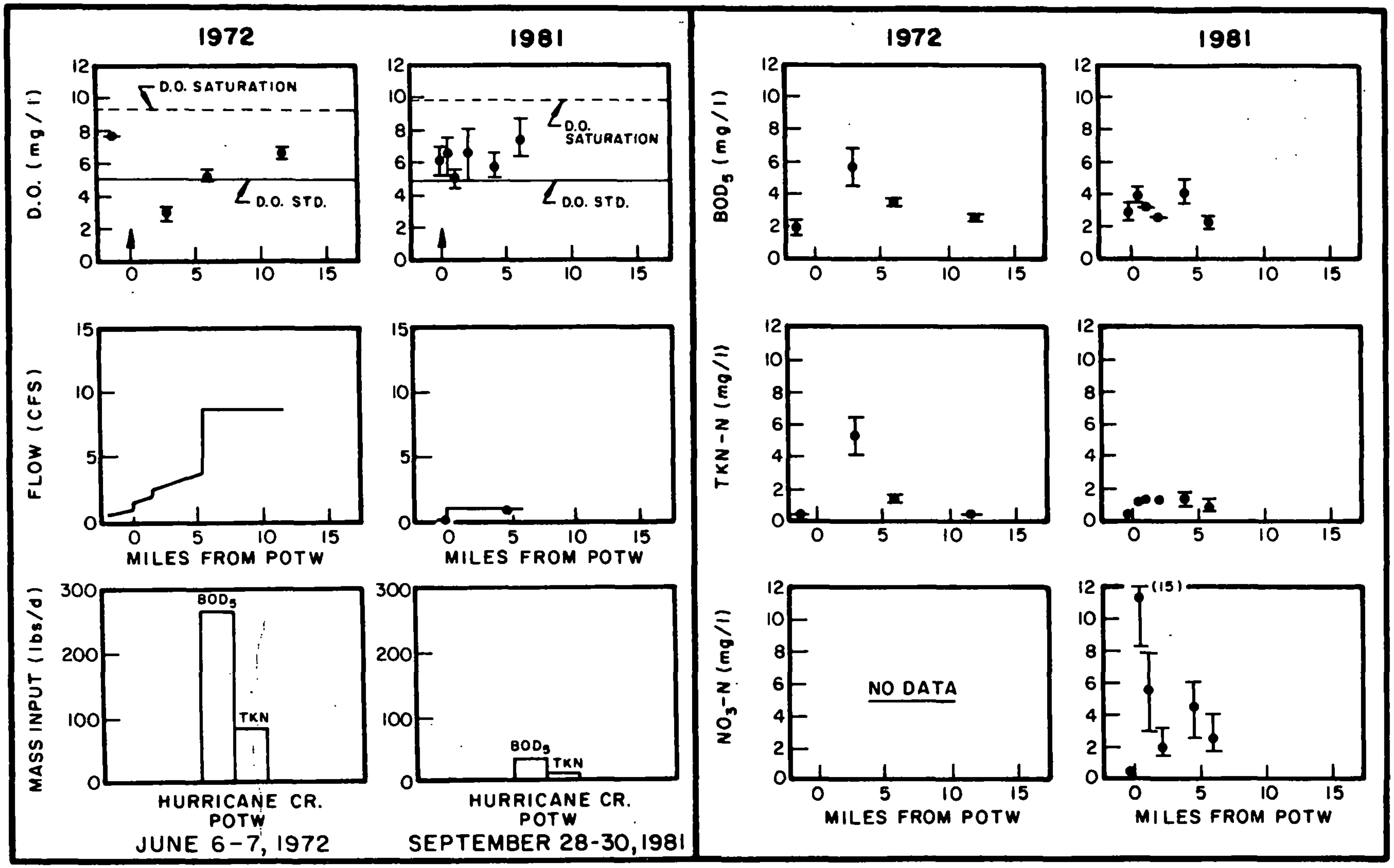


Figure C-13

Water Quality Comparions for Hurricane Creek, West Virginia
(Trickling Filter Secondary Treatment to Oxidation Ditch Secondary Treatment)

Figure C-14

POST AUDIT FACT SHEET

NO. 5 WATER BODY NAME:	STREAM / RIVER / LAKE / ESTUARY		TRIBUTARY TO:	STATE:	MODEL USED TO MAKE WLA:
Hurricane Creek	STREAM	X	Kanawaha River	West Virginia	YES X NO

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH: less than 1.0 ft

APPROX. VELOCITY: 0.04 ft/sec at 7Q10

SLOPE: -

7Q10 FLOW: 0.1 cfs upstream of POTW

	BEFORE			AFTER			
POINT SOURCE DESIGN:		Hurricane POTW	TOTAL		Hurricane POTW	TOTAL	% CHANGE
FLOW (MGD) =							
BOD_5 (mg/l) / (lbs/d) =							
NH_3 (mg/l) / (lbs/d) =							
COMMENT:							
POINT SOURCE OPERATING:			TOTAL			TOTAL	% CHANGE
FLOW (MGD) =		0.29	0.29		0.64	0.64	+ 120%
BOD_5 (mg/l) / (lbs/d) =		110/(267)	267		4.7/(25)	25	- 90.6%
NH_3 (mg/l) / (lbs/d) =		34/(83)	83		1.4/(7.5)	7.5	- 91.0%
COMMENT:		Trickling Filter			Oxidation Ditch		
RIVER CHEMISTRY:							
AVERAGE D.O. (mg/l) =		5.6			6.3		+ 12.5%
MINIMUM D.O. (mg/l) =		2.6			4.5		+ 73.1%
MAXIMUM BOD_5 (mg/l) =		5.6			5.1		- 8.9%
MAXIMUM NH_3 (mg/l) =		5.4			1.3		- 75.9%
MAX. UNIONIZED NH_3 (mg/l) =		0.007			0.004		- 42.8%

COMMENTS:

POST AUDIT MODEL FACT SHEET

WATER BODY NAME: HURRICANE CREEK

MODEL TYPE: STREETER-PHELPS RIVER **CALIBRATED:** YES X NO ___

MODEL NAME: CADEP (USEPA REGION III) **VALIDATED:** YES ___ NO X

WASTE LOAD ALLOCATION

RIVER FLOW:[1] 0.1 CFS

RIVER TEMP.: 26.7°C

POINT SOURCE INFO:

	HURRICANE POTW
Q (MGD) =	1.55
BOD_5 (mg/l) =	5.0
TKN (mg/l) =	2.0

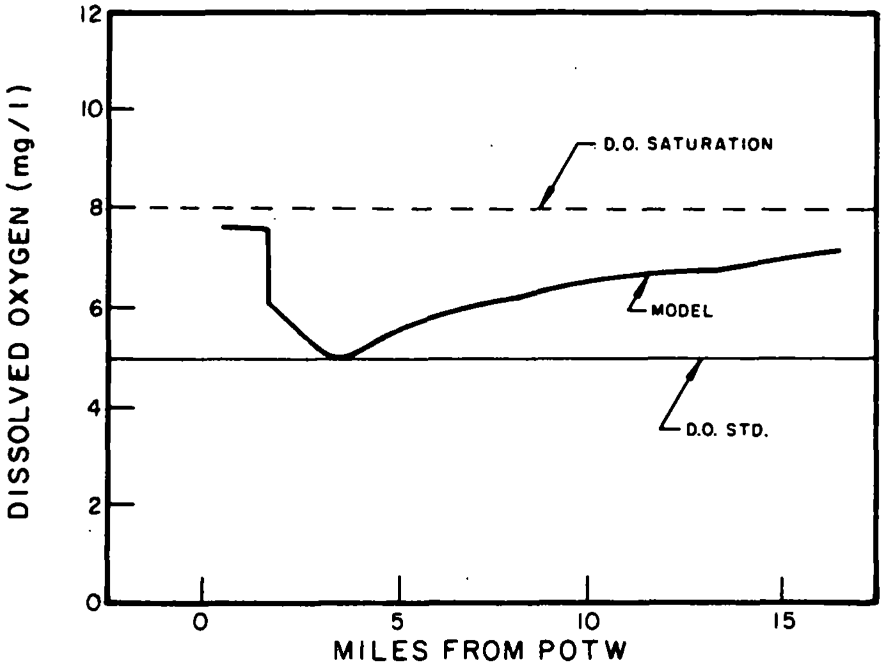
UPSTREAM INFO:

Q (CFS) =	0.1
BOD_5 (mg/l) =	6.2[2]
TKN (mg/l) =	—

COMMENTS:

1- 7Q10

2- ULT. CBOD + NBOD



POST AUDIT

RIVER FLOW: 0.16 CFS

RIVER TEMP.: 15°C

POINT SOURCE INFO:

	HURRICANE POTW
Q (MGD) =	0.64
BOD_5 (mg/l) =	4.7
TKN (mg/l) =	1.4

UPSTREAM INFO:

Q (CFS) =	0.16
BOD_5 (mg/l) =	3.0[1]
TKN (mg/l) =	0.4

COMMENTS:

1- ULT. CBOD + NBOD

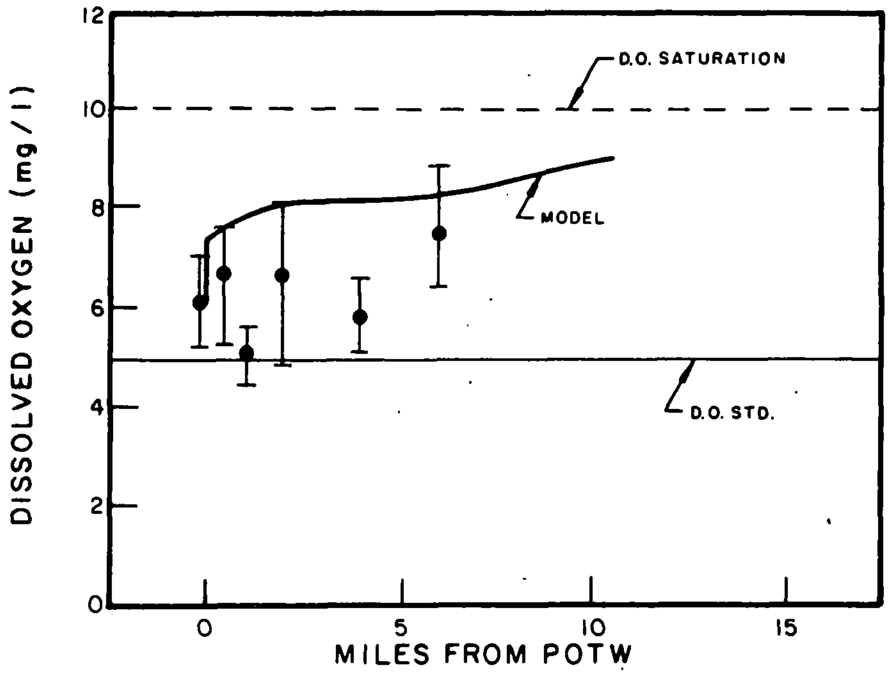


Figure C-15

Project Case Study
Water Body: South River, Virginia

The South River is located in the northwestern part of Virginia. The South River joins the Middle River and North River near Port Republic, Virginia to form the South Fork Shenandoah River. The watershed consists primarily of agricultural and forest land, with the only heavy populated area being the city of Waynesboro. River flows approach the 7Q10 low flow on a regular basis in summer months.

Water quality problems of primary concern are low dissolved oxygen concentrations as well as large diurnal fluctuations in dissolved oxygen as a result of photosynthesis and respiration by attached algae and higher level aquatic plants. Wastewater discharged to the river by both municipalities and industries are expected to account for about 27 cfs in the future. This waste flow will at 7Q10 account for about 50 percent of the river flow downstream of the point source inputs.

In 1974, the state of Virginia performed initial mathematical modeling of the South River to develop preliminary wasteload allocations. At this time, instream nitrification and attached algal photosynthesis and respiration were defined as the major issues influencing river dissolved oxygen levels.

Wasteload allocations developed required point sources to reduce ammonia levels in their effluents. After reduction of ammonia by DuPont, additional water quality data sets were collected and used to recalibrate and verify a water quality model by USEPA, Region III.

Review of data collected after installation of nitrification facilities by DuPont indicated improved dissolved oxygen levels and reduced ammonia levels in the river (Figures C-16, C-17). Monitoring data collected by the state of Virginia at river mile 18.5 also reflect the upgrade of treatment at DuPont. Dissolved oxygen data (Figure C-18) from summer periods before the plant upgrade indicated a mean dissolved oxygen concentration of 5.6 mg/l while after the AWT upgrade dissolved oxygen levels averaged 7.0 mg/l. Similarly, ammonia levels before upgrade averaged 1.5 mg/l and after upgrade ammonia concentrations averaged 0.3 mg/l. Biological macroinvertebrate data collected in 1970, five miles downstream of DuPont showed 99 percent of the species to be bloodworms and sludge worms, pollution tolerent group. Biological data collected in 1979, four miles downstream of DuPont, still indicated the presence of pollution dominant species but also indicated the presence of facultative and pollution intolerant species. No data were uncovered concerning recreational use of the river in the framework of this project.

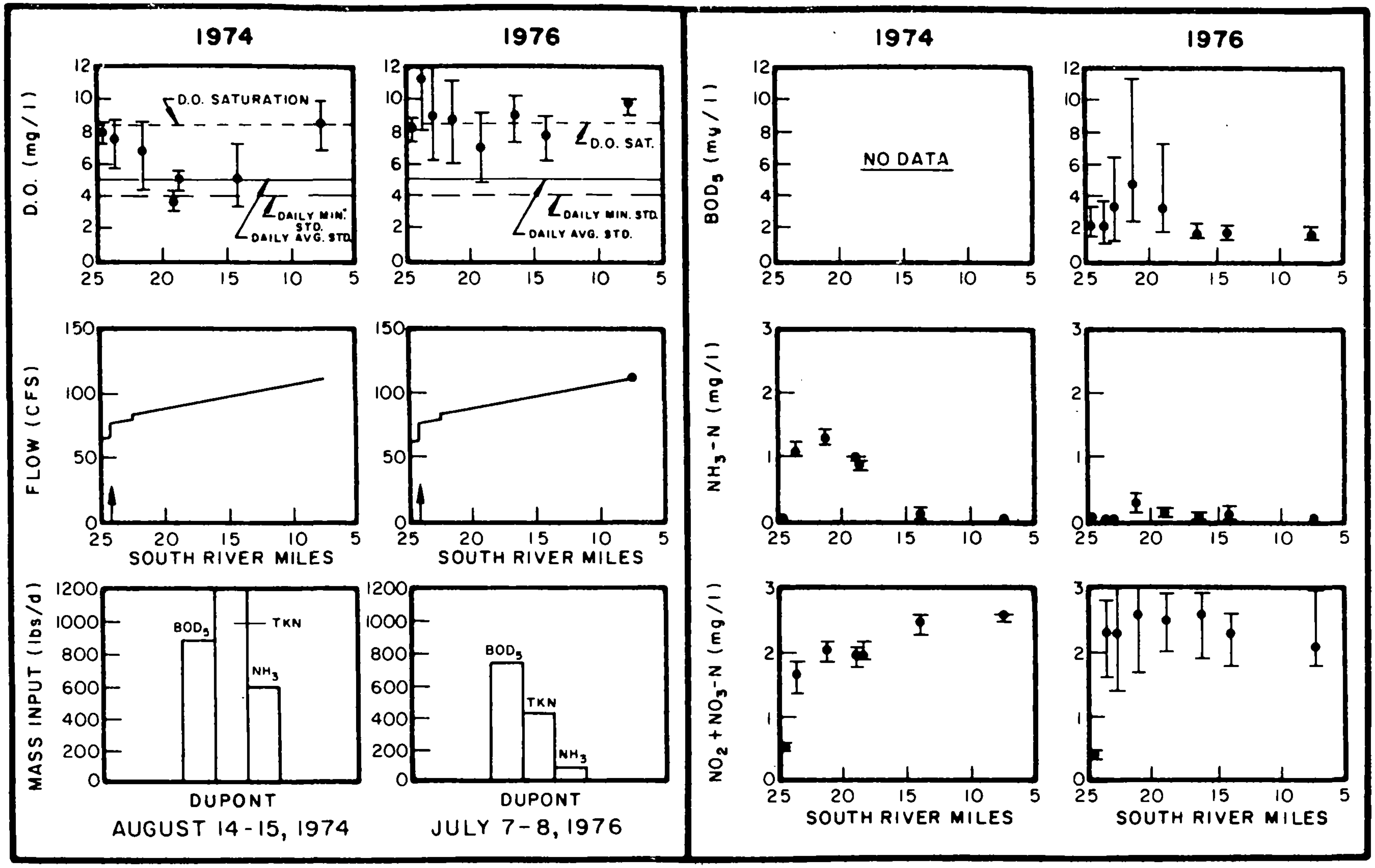


Figure C-16

Water Quality Comparisons for South River, Virginia
(Trickling Filter to Nitrification at DuPont only)

Figure C-17

POST AUDIT FACT SHEET

NO. 6 WATER BODY NAME:	STREAM / RIVER / LAKE / ESTUARY	TRIBUTARY TO:	STATE:	MODEL USED TO MAKE WLA:
South River	X	South Fork Shenandoah	Virginia	YES X NO

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH= 2 ft at 7Q10

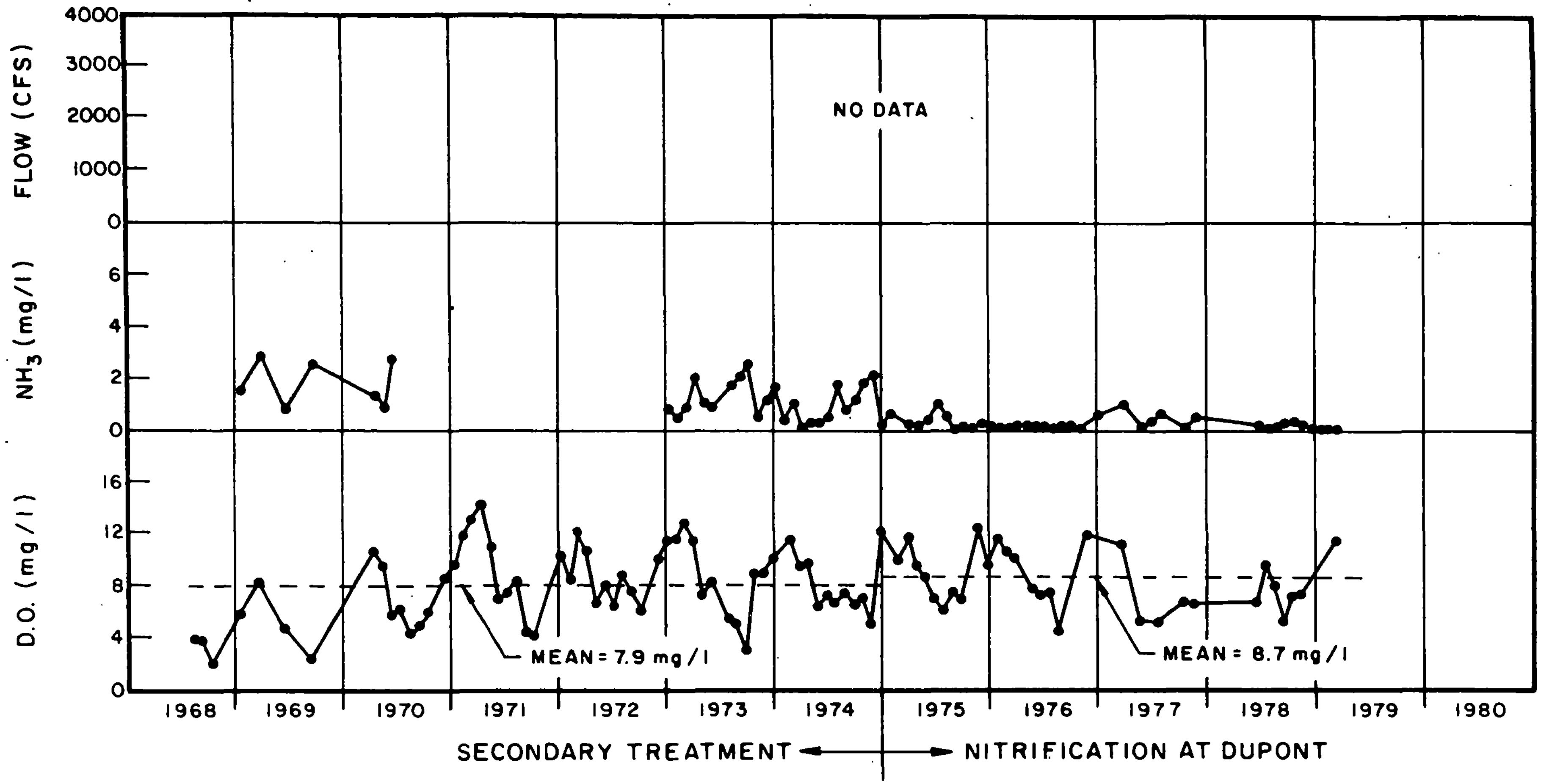
APPROX. VELOCITY= 0.5 to 1.5 ft/sec

SLOPE=

7Q10 FLOW= 27 cfs

	BEFORE Dupont	BEFORE Waynesboro POTW	BEFORE TOTAL	AFTER Dupont	AFTER Waynesboro POTW	AFTER TOTAL[2]	% CHANGE
POINT SOURCE DESIGN:							
FLOW (MGD) =				10.6	4.[1]	17.2	-
BOD_5 (mg/l) / (lbs/d)=				6.7/(600)	7.5/(250)	982	-
NH_3 (mg/l) / (lbs/d)=				0.6/(50)	2.0/(66)	139	-
COMMENT:	Act.Sludge	High Rate T.F.			RBC/Filters		
POINT SOURCE OPERATING:			TOTAL			TOTAL[2]	% CHANGE
FLOW (MGD)=	9.3	2.3	12.6	7.7	1.8	9.8	- 22%
BOD_5 (mg/l) / (lbs/d)=	11.5/(882)	30/(575)[3]	1457	11.3/(737)	31/(478)	1215	-16.7%
NH_3 (mg/l) / (lbs/d)=	7.9/(614)	7.4/(138)	766	.81/(53)	8.2/(126)	179	-76.6%
COMMENT:							
RIVER CHEMISTRY:							
AVERAGE D.O. (mg/l)=		6.4			8.7		+ 36%
MINIMUM D.O. (mg/l)=		3.2			4.8		+ 50%
MAXIMUM BOD_5 (mg/l)=		-			11.3		-
MAXIMUM NH_3 (mg/l)=		1.4			0.45		-67.9%
MAX. UNIONIZED NH_3 (mg/l)=		0.018			0.004		-77.8%

COMMENTS: 1. From WLA not operating at this design during July, 1976; 2. Includes duPont, Waynesboro, and also Crompton-Shenandoah, ThioKol; 3. Assigned at 30 mg/l;



JUNE, JULY, AUGUST & SEPTEMBER

	MEAN (mg/l) BEFORE	MEAN (mg/l) AFTER	% CHANGE	STANDARD DEVIATION (mg/l) BEFORE	STANDARD DEVIATION (mg/l) AFTER
FLOW[1]	—	—	—	—	—
D.O.	5.6	7.0	+25%	2.8	2.1
NH_3	1.5	0.3	−80%	0.65	0.27

1-UNITS = CFS

DATA SOURCE STORET

Figure C-18

Time History Data Analysis for South River

(Station Code: 1BSTH018.50 · Agency Code: 21VASWCB)

Project Case Study
Water Body: Potomac Estuary, Maryland

The Potomac Estuary located in the eastern United States, forms the border between the states of Virginia and Maryland. Upstream of the District of Columbia, the river is free flowing while downsteam of the capitol it is estuarine. The Potomac River receives treated wastes from a population in excess of three million people. In recent years, treated sewage flow discharged to the Potomac in the Capitol district vicinity has reached about 425 mgd.

In the 1950s and 1960s, the Potomac River, which at that time was receiving primary and secondary treated wastewaters, was experiencing low summer dissolved oxygen concentrations (approximately 2.0 to 3.0 mg/l), elevated coliform levels and persistent blue-green algal blooms. About this time, agreements were made to remove some 96 percent of the phosphorus and BOD_5 and 85 percent of the NBOD from the areas' wastewaters before discharging them to the Potomac. This clean-up program which has been in effect for a decade, has resulted in Potomac River water quality improvements.

Data, displayed on Figure C-19, show dissolved oxygen, BOD, and ammonia improvements in the river between 1977 and 1981. At these times, river flows and temperatures were about equal, therefore, water quality changes reflect differences in treatment practices. The principal action taken during this time was upgrading (Figure C-20) the Blue Plains POTW from secondary treatment and phosphorus removal to secondary treatment, phosphorus and NBOD removal. It is, therefore, assumed that the observed Potomac quality improvements are, at least in part, due to the upgrade in treatment at this facility.

Another measure of the Potomac quality improvement is presented as summer dissolved oxygen concentrations measured near and at the Woodrow Wilson Bridge over the time period 1969 to 1981 (Figure C-21). Although differences in summer flows complicate conclusions which can be drawn from this data, it is evident that there is a general trend toward increased dissolved oxygen levels in recent years.

Because of the complex influences and responses of Potomac River water quality, no attempt has been made as part of this study to address the impact of phosphorus removal at Blue Plains on algal levels. This is a more difficult issue to address and requires more data input and review time than was available as part of this project. A report recently complete (Reference 12, Section 5) discusses these issues in more detail.

With respect to recreational improvements in the river, there is some indication that large mouth bass are now routinely caught by sport fishermen in the area of the capitol. Further, there has been a general increase in the annual fish landings by commercial fisherman in the upper reaches of the Potomac. Generally, fish landings have been increasing over the decade of the 1970s. However, it is not obvious from these data that pollution intolerant fish species, such as bass, are more abundant in the river. Although both dissolved oxygen levels and fish landings appear to be increasing in time as noted, the correlation of the two factors only yields a weak relationship (seven percent variance removed).

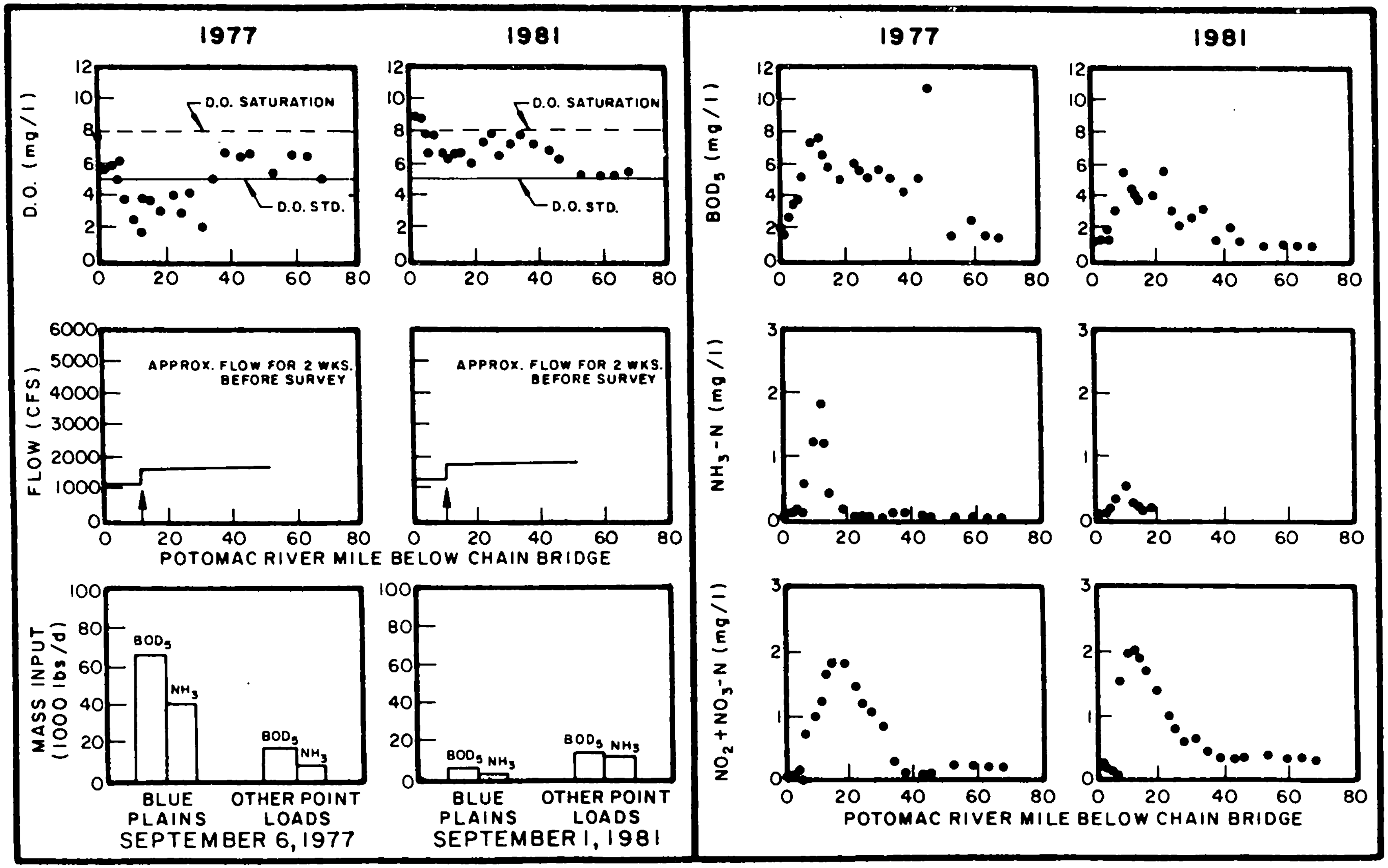


Figure C-19

Water Quality Comparions for Potomac Estuary, Maryland
(Secondary Treatment + P-Removal to Secondary Treatment + P-Removal + Nitrification)

Figure C-20

POST AUDIT FACT SHEET

NO. 7 WATER BODY NAME:	STREAM / RIVER / LAKE / ESTUARY	TRIBUTARY TO:	STATE:	MODEL USED TO MAKE WLA:
Potomac River Estuary	ESTUARY X	Chesapeake Bay	Maryland	YES X NO

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH= 15 ft

APPROX. VELOCITY=[1] 0.1 ft/sec

SLOPE= N/A

7Q10 FLOW= 560 cfs

	BEFORE			AFTER			
POINT SOURCE DESIGN:	Blue Plains	Other Point Sources	TOTAL	Blue Plains	Other Point Sources	TOTAL	% CHANGE
FLOW (MGD) =				305			
BOD_5 (mg/l) / (lbs/d)=				5.0/(12700)			
NH_3 (mg/l) / (lbs/d)=				2.4/(6130)[3]			
COMMENT:	Sec.Treat.	Sec.Treat.		Ammonia Removal			
POINT SOURCE OPERATING:[5]			TOTAL			TOTAL	% CHANGE
FLOW (MGD)=	271	82	353	317	99	416	
BOD_5 (mg/l) / (lbs/d)=	28.8/(65000)	-/(13701)	78701	1.5/(3965)	-/(14200)	18165 lbs/d	- 77%
NH_3 (mg/l) / (lbs/d)=	17.7/(40000)[4]	-/(9394)	49394	0.61/(1612)	-/(12774)	14386 lbs/d	- 71%
COMMENT:							
RIVER CHEMISTRY:							
AVERAGE D.O. (mg/l)=		4.3[2]			7.6		+ 77%
MINIMUM D.O. (mg/l)=		1.8			6.0		+ 233%
MAXIMUM BOD_5 (mg/l)=		7.6			5.6		- 26%
MAXIMUM NH_3 (mg/l)=		1.8			0.5		- 72%
MAX. UNIONIZED NH_3 (mg/l)=		0.009			0.002		- 78%

COMMENTS: 1. At 7Q10; 2. Between mile zero and mile 30.0; 3. Total kjeldahl nitrogen; 4. Total nitrogen; 5. Upstream flow for both cases could account for another 30,000 lbs/day BOD and 650 lbs/day NH_3;

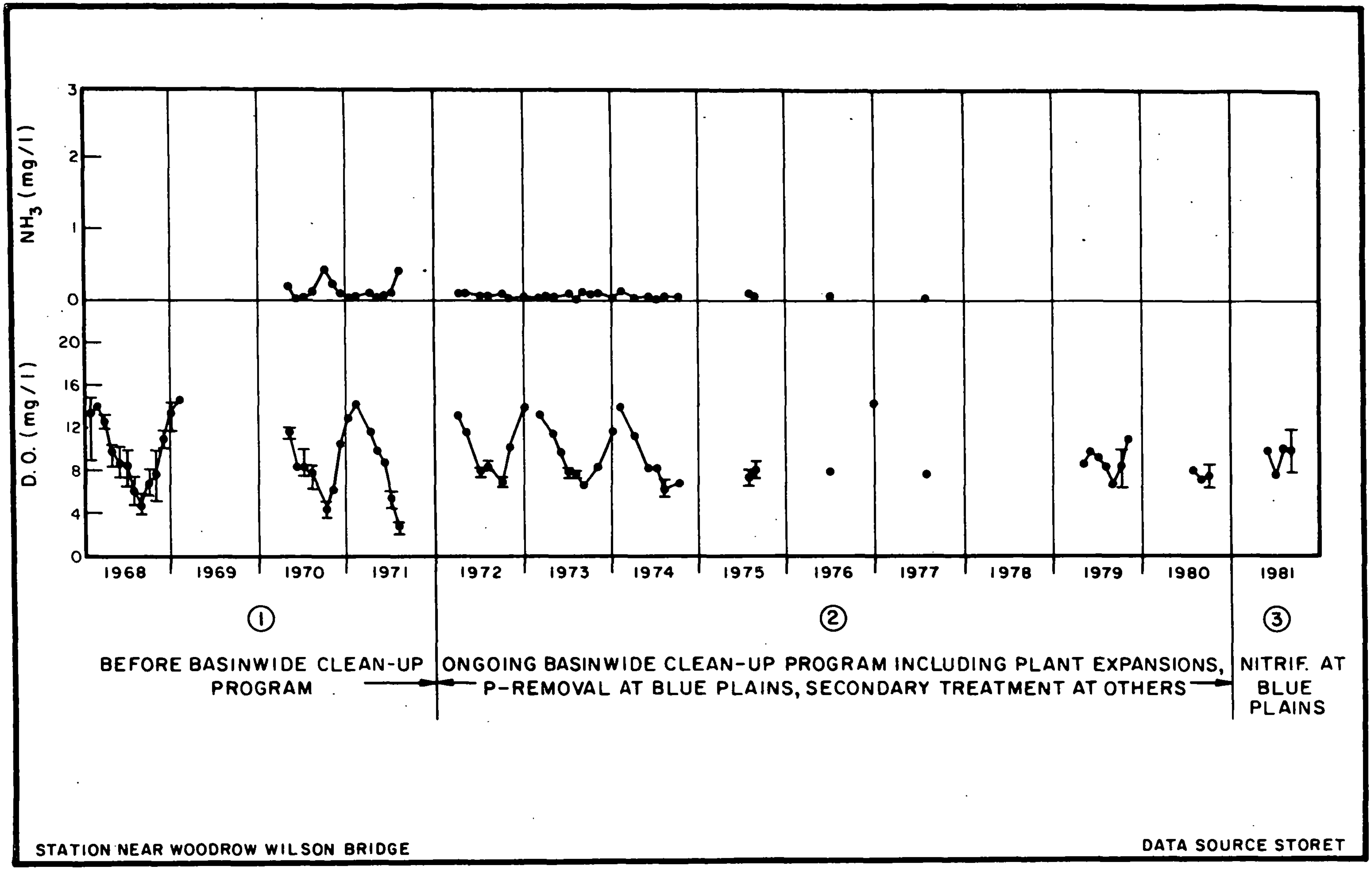


Figure C-21

Time History Analysis for Potomac River

(① — Station Code: 100130 · Agency Code: 1110NET)

(②,③ Station Code: POT-CONS-002 · Agency Code: 11121TWQ)

Project Case Study
Water Body: Clinton River, Michigan

The Clinton River, located in eastern Michigan, discharges to Lake St. Clair which forms the Detroit River and flows into the Western Basin of Lake Erie. The entire river basin drains about 760 square miles of the state. The area of interest is between the cities of Pontiac and Rochester, 35 miles upstream from Lake St. Clair. In this reach, the major wastewater input is from the city of Pontiac.

In 1958, the Michigan Water Resources Commission performed a water quality monitoring and modeling study on the river to develop the waste assimilation capacity. Data from this study, shown on Figure C-22, exhibit dissolved oxygen levels in the river as low as 0.4 mg/l and BOD_5 levels as high as 32.0 mg/l at summer low flow conditions. At the time of this survey, 74 percent of the wastewaters entering the river received secondary treatment (trickling filter and activated sludge) while the remaining wastewaters underwent only primary treatment (Figure C-23).

Subsequent surveys in 1973 and 1976 were conducted after new treatment plants had been constructed and all wastewaters were receiving a high level secondary treatment. At the time of the 1976 survey, both the Pontiac East Boulevard and the Auburn treatment plants were achieving significant levels of nitrification although they were only designed for phosphorus removal. Effluent BOD_5 and NH_3 concentrations from both plants were about 5.0 and 0.5 mg/l, respectively. Water quality data shown on Figure C-22, indicate greatly improved dissolved oxygen concentrations and reduced BOD_5 concentrations in response to the upgrade in treatment plant efficiency.

Additional chemical water quality data available for review was obtained from the USEPA STORET data system. These data (Figure C-24) were collected near the dissolved oxygen sag point (river mile 40 to 45). The data, both qualitatively and quantitatively, show improved conditions resulting from upgraded treatment. Data from 1958 indicated that under conditions of secondary treatment, summer instream dissolved oxygen concentrations were depressed to near 0.0 mg/l. As shown in the monitoring data, summer oxygen concentrations at upgraded treatment levels are not less than 5.0 mg/l.

Further, as treatment is upgraded at each facility through the 1970s, summer mean oxygen concentrations gradually improve. In the early 1970s when the East Boulevard and Auburn POTWs had secondary treatment plus phosphorus removal, summer mean river oxygen concentrations averaged 7.2 mg/l. After phosphorus removal was implemented at the Auburn POTW, summer average oxygen concentrations increased again slightly to 7.3 mg/l. At the end of the 1970s when the effluent flow from both plants was combined and treated with nitrification, phosphorus removal, and effluent polishing, average oxygen concentrations are further increased to 8.5 mg/l. Ammonia concentrations show similar trends, starting at 0.47 mg/l and decreasing to 0.27 and 0.06 at the respective levels of treatment. These data along with the 1958 and 1976 intensive survey data show improvements in river water quality that are directly associated with improvements in wastewater treatment techniques at both the Pontiac treatment facilities.

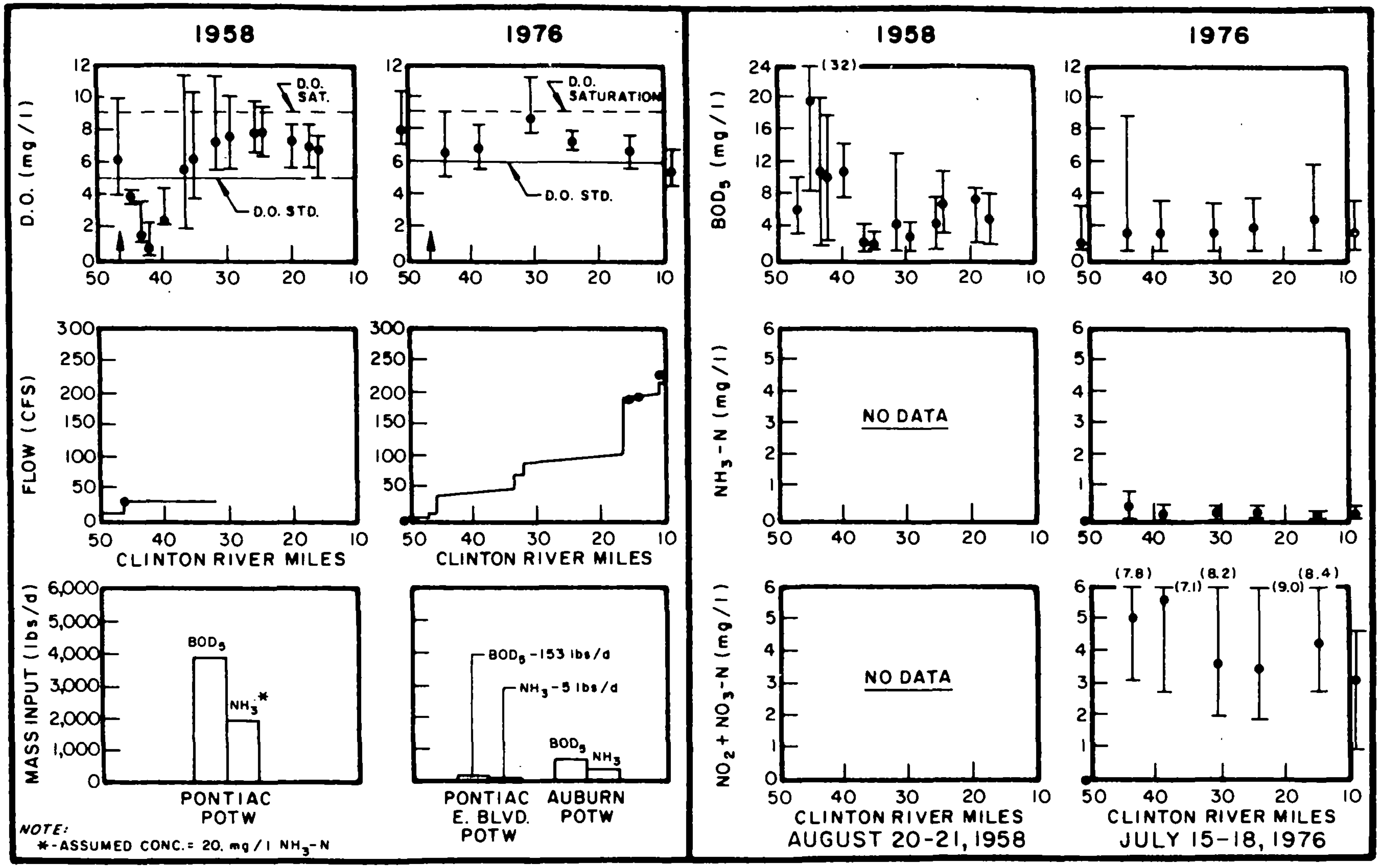


Figure C-22

Water Quality Comparisons for Clinton River, Michigan
(Secondary Treatment to Sec. + Nitrification)

Figure C-23

POST AUDIT FACT SHEET

NO. 8 WATER BODY NAME: Clinton River	STREAM / RIVER X / LAKE / ESTUARY	TRIBUTARY TO: Lake St. Clair	STATE: Michigan	MODEL USED TO MAKE WLA: YES X NO

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH: 2 to 3 feet

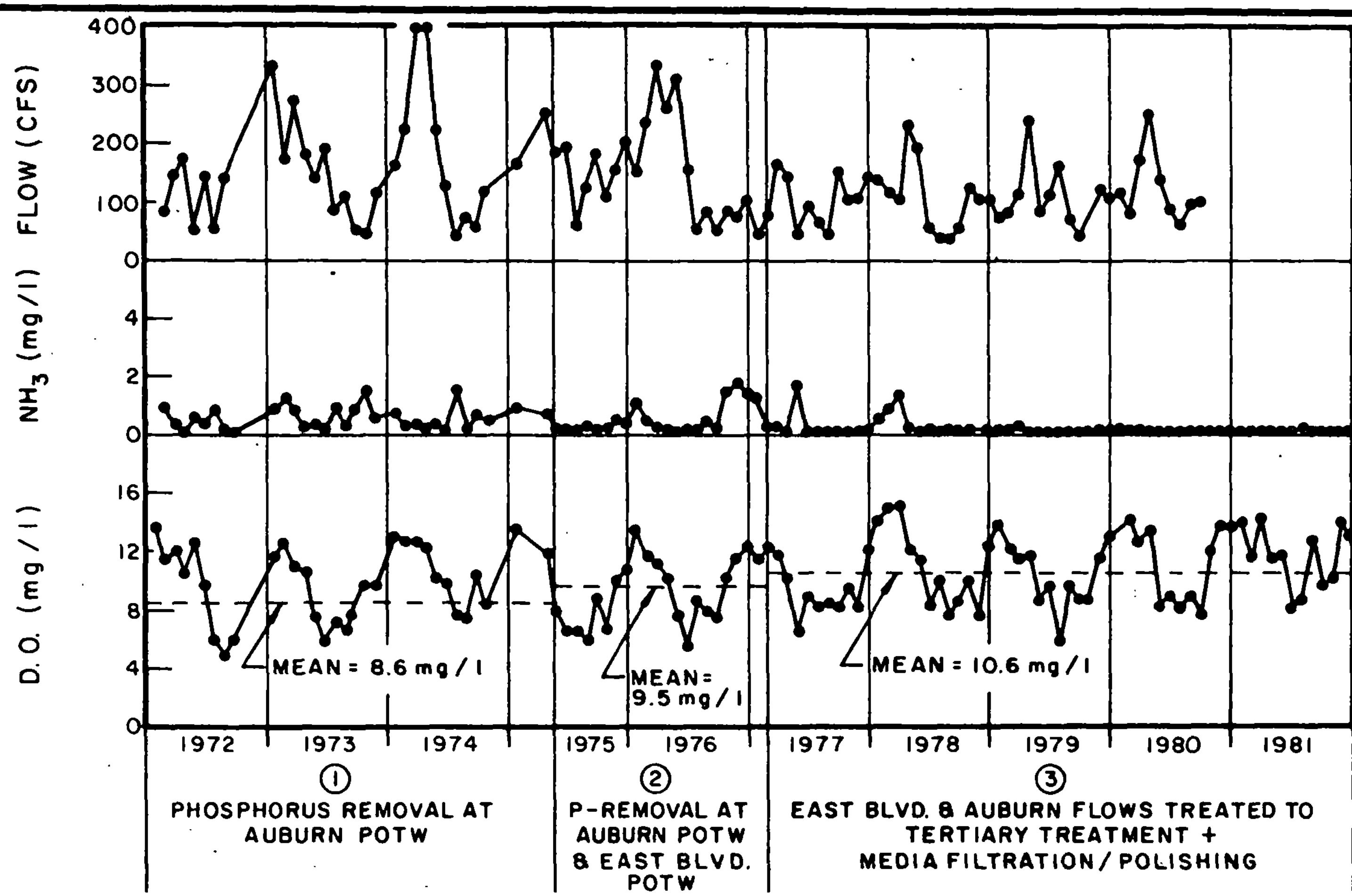
APPROX. VELOCITY: 0.5 ft/sec

SLOPE: -

7Q10 FLOW: 1.4 cfs upstream of POTW's

	BEFORE[3]			AFTER[3]			
POINT SOURCE DESIGN:	Pontiac POTW		TOTAL	Pontiac East Blvd.	Auburn POTW	TOTAL	% CHANGE
FLOW (MGD) =	-			9.4	10.0		
BOD_5 (mg/l) / (lbs/d) =	-			-	-		
NH_3 (mg/l) / (lbs/d) =	-			-	-		
COMMENT:	T.F. + Act.Sludge			Sec.Treat.[4]	Sec.Treat.[4]		
POINT SOURCE OPERATING:			TOTAL			TOTAL[2]	% CHANGE
FLOW (MGD) =	11.6		11.6	3.2	17.6	20.8	+ 79.3%
BOD_5 (mg/l) / (lbs/d) =	39/(3817)		3817	5/(133)	4/(587)	720	- 81.0%
NH_3 (mg/l) / (lbs/d) =	20/(1934)[1]		1934	0.2/(5.3)	1.1/(162)	167	- 91.0%
COMMENT:	T.F. + Act.Sludge			Sec.Treat. Act.Sludge	Sec.Treat. Act.Sludge		
RIVER CHEMISTRY:							
AVERAGE D.O. (mg/l) =		3.8			7.1		+ 87.0%
MINIMUM D.O. (mg/l) =		0.4			5.2		+1200.0%
MAXIMUM BOD_5 (mg/l) =		32			3.2		- 90.0%
MAXIMUM NH_3 (mg/l) =		-			0.9		-
MAX. UNIONIZED NH_3 (mg/l) =		-			0.008		-

COMMENTS: 1. NH_3 assumed equal to 20 mg/l; 2. BOD_5 and NH_3 as pounds per day; 3. Before survey 1958, after 1976; 4. Designed as secondary treatment but attaining significant inplant nitrification;



JUNE, JULY, AUGUST & SEPTEMBER

	MEAN (mg/l)			STANDARD DEVIATION (mg/l)		
PERIOD →	①	②	③	①	②	③
FLOW[1]	92	112	79	37	60	38
D.O.	7.2	7.3	8.5	1.5	1.3	1.1
NH_3	0.47	0.27	0.06	0.43	0.11	0.06

1-UNITS = CFS

DATA SOURCE STORET

Figure C-24
Time History Data Analysis for Clinton River, Michigan
(Station Code: 6302S2 · Agency Code: 21MICH)

The original 1958 wasteload allocation work was performed using analytical equations not a computer based model. Essentially, this analysis developed BOD_5 oxidation rates and dissolved oxygen reaeration rates needed for the Streeter-Phelps equation from instream BOD and dissolved oxygen data. The analysis did not include nitrification, SOD, or photosynthesis and respiration.

To evaluate the goodness of fit of the original 1958 model, a dissolved oxygen projection curve was developed in this study (Figure C-25) for the appropriate 1976 loading conditions from the projections presented in the 1958 report. This simulation is plotted against the 1976 observed water quality dissolved oxygen data. The model simulation, although somewhat over optimistic, does show the significant improvement in dissolved oxygen levels measured in 1976.

Within the framework of this project no data were available to assess biological improvements in the river or any increased recreational activities as stimulated by the upgraded treatment levels.

POST AUDIT MODEL FACT SHEET

WATER BODY NAME: CLINTON RIVER

MODEL TYPE: STREETER-PHELPS **CALIBRATED:** YES X NO ___

MODEL NAME: ANALYTICAL EQUATION **VALIDATED:** YES ___ NO X

WASTE LOAD ALLOCATION

RIVER FLOW:[1] 9.1 CFS

RIVER TEMP.: 21°C

POINT SOURCE INFO:

	TOTAL
Q (MGD) =	___
BOD_5 (mg/l) =	___

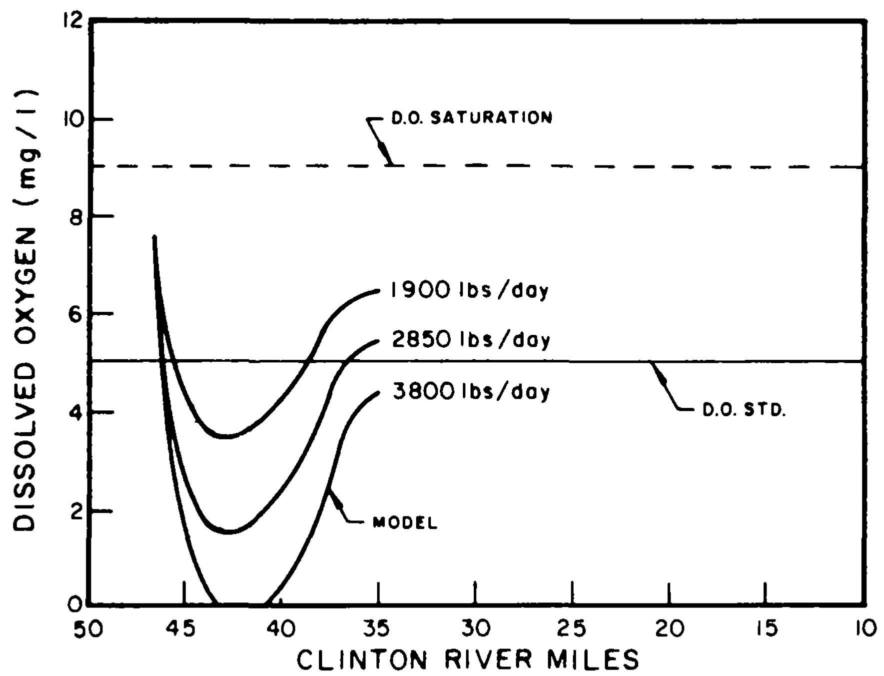
UPSTREAM INFO:

Q (CFS) = 9.1

BOD_5 (mg/l) = 6

COMMENTS:

1 UPSTREAM FROM POTW'S



POST AUDIT

RIVER FLOW: 9 CFS

RIVER TEMP.: 18°C

POINT SOURCE INFO:

	PONTIAC E. BLVD.	AUBURN
Q (MGD) =	3.2	17.6
BOD_5 (mg/l) =	5	4

UPSTREAM INFO:

Q (CFS) = 9

BOD_5 (mg/l) = 1.0

COMMENTS:

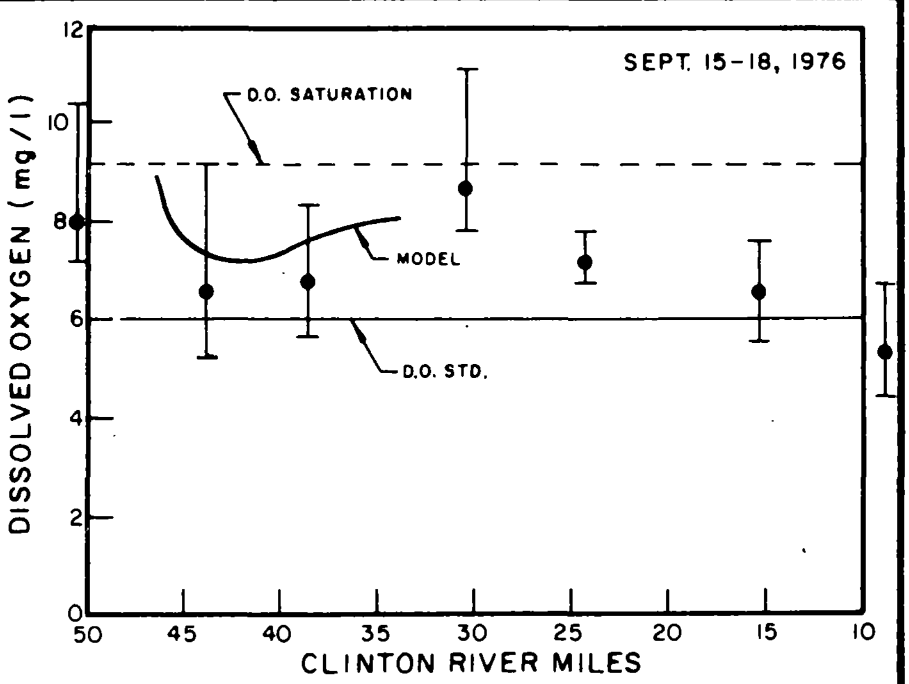


Figure C-25

Project Case Study
Water Body: Ottawa River, Ohio

The Ottawa River is located in north western Ohio. The river flows west from LaFayette to Lima and then north to join the Auglaize River near Defiance, Ohio. The river drains some 373 square miles of agricultural land. Major sources of pollution are located in the city of Lima which is about 38 miles upstream from the river mouth.

In 1966, the Department of the Interior reported median ammonia concentrations of more than 60.0 mg/l in the river downstream of the city of Lima. Further, the Ohio Department of Health has reported October 1964 dissolved oxygen concentrations ranged from 0.0 to 1.0 mg/l for the 38 miles of river from Lima to the mouth. These data coincide with biological findings that at this time, the river near Lima was totally devoid of fish life and only pollution tolerant macroinvertebrates existed in the river.

Literature indicates that CSOs, municipal and industrial discharges from Lima were responsible for these levels of instream pollution. Over the last few decades efforts which have been initiated have greatly reduced pollution inputs to the river. In the mid-1970s these efforts continued and the Ohio Environmental Protection Agency undertook a study to assess the associated instream water quality improvements.

The first data sets from these studies presented on Figures C-26 and C-27 show Ottawa River data collected in the summers of 1974 and 1975. The studies represent post-audit conditions in response to ongoing clean-up of the river from the 1950s and 1960s. The same data set represents pre-audit conditions for later nitrification at the Lima POTW.

During the summer of 1974 and 1975 average dissolved oxygen concentrations ranged from a low of 2.8 to a high of 8.3 mg/l, average ammonia concentrations were near 20.0 mg/l, and the maximum un-ionized ammonia concentration was 6.2 mg/l (Figure C-28). Although, these data still indicate poor water quality, they are greatly improved over those data collected in the mid-1960s.

After 1975, nitrification at the Lima POTW reduced effluent ammonia concentrations to less than 1.0 mg/l. This change, plus improved BOD_5 removals at the plant, is reflected in increased river oxygen levels, reduced ammonia levels, and greatly reduced ammonia concentrations as shown in the 1977 intensive water quality data. Dissolved oxygen concentrations, however, are still depressed below 5.0 mg/l; ammonia concentrations still exceed 10.0 mg/l and un-ionized ammonia concentrations exceed 0.1 mg/l. These water quality conditions still exist because although the Lima POTW reduced effluent BOD_5 by an additional 80 percent and reduced effluent ammonia by an additional 90 percent, the two industries have not reduced effluent BOD and ammonia concentrations. Both the Vistron Corporation and Standard Oil have slightly increased effluent BOD_5 and ammonia levels between 1974 and 1977.

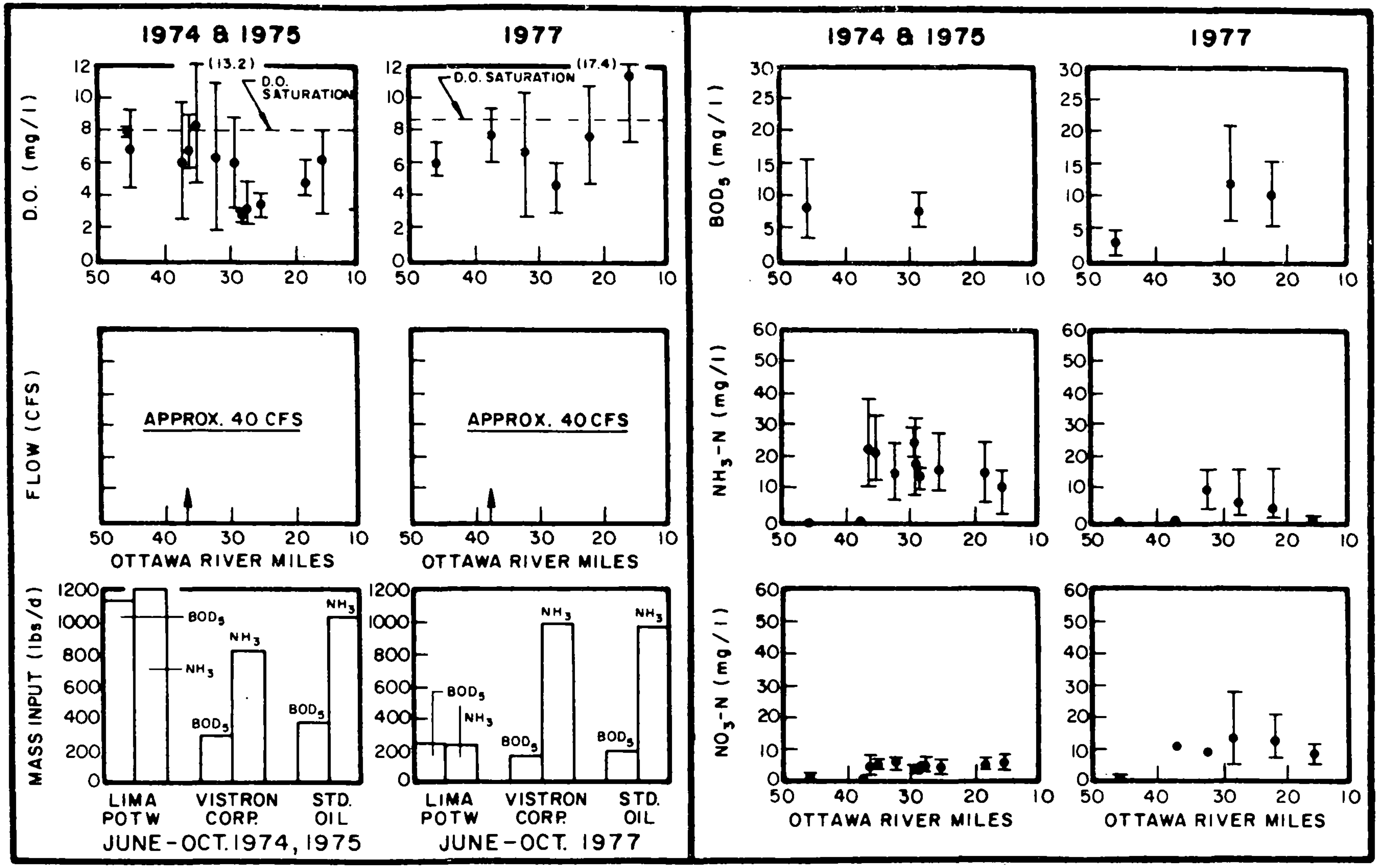


Figure C-26

Water Quality Comparisons for Ottawa River, Ohio
(Secondary Treatment to Secondary + Nitrification)

Figure C-27

POST AUDIT FACT SHEET

NO. 9 WATER BODY NAME:	STREAM / RIVER / LAKE / ESTUARY	TRIBUTARY TO:	STATE:	MODEL USED TO MAKE WLA:
Ottawa River	X (STREAM)	Auglaize & Maumee River	Ohio	YES X[2] NO

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH: N/A

APPROX. VELOCITY: N/A

SLOPE: 4 feet per mile

7Q10 FLOW: near zero upstream of point sources

	BEFORE			AFTER			
POINT SOURCE DESIGN:	Lima POTW	Industries[1]	TOTAL	Lima POTW	Industries[1]	TOTAL	% CHANGE
FLOW (MGD) =							
BOD_5 (mg/l) / (lbs/d)=							
NH_3 (mg/l) / (lbs/d)=							
COMMENT:							
POINT SOURCE OPERATING:			TOTAL			TOTAL	% CHANGE
FLOW (MGD)=	15.2	6.9	22.1	16.5	7.9	24.4	+ 10.4%
BOD_5 (mg/l) / (lbs/d)=	8.6/(1114)	11.3/(650)	1764	1.8/(243)	14.6/(960)	1203	- 31.8%
NH_3 (mg/l) / (lbs/d)=	10/(1239)	26.8/(1543)	2782	0.9/(231)	29.3/(1933)	2164	- 22.2%
COMMENT:							
RIVER CHEMISTRY:							
AVERAGE D.O. (mg/l)=		5.4			7.5		+ 38.9%
MINIMUM D.O. (mg/l)=		2.0			2.8		+ 40.0%
MAXIMUM BOD_5 (mg/l)=		10.5			21		+ 100.0%
MAXIMUM NH_3 (mg/l)=		38			17		- 55.3%
MAX. UNIONIZED NH_3 (mg/l)=		6.2			0.53		- 91.5%

COMMENTS: 1. Vistron Corp. & Standard Oil Refinery; 2. Not available for incorporation in this project;

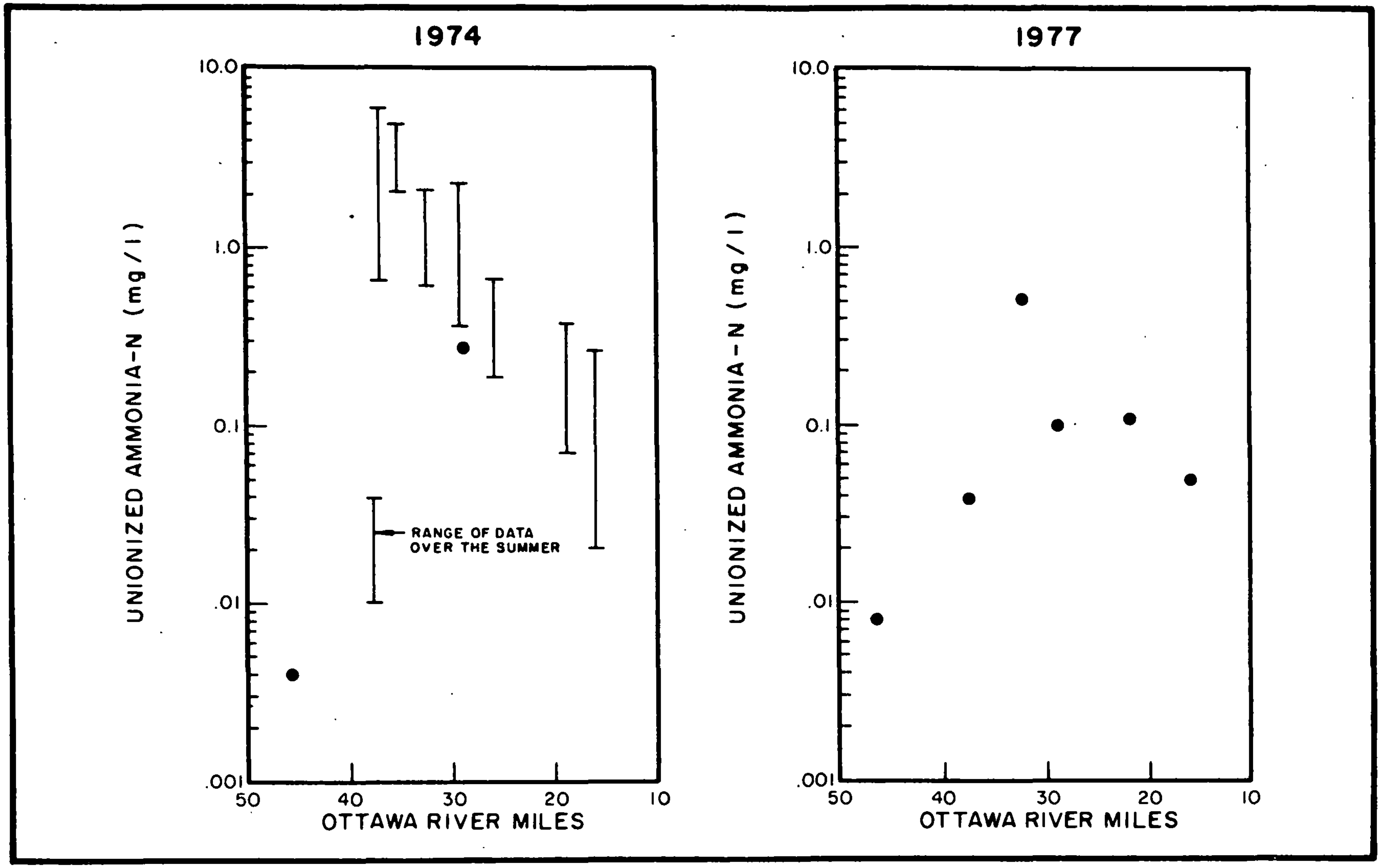


Figure C-28

Water Quality Comparisons for Ottawa River, Ohio
(Secondary Treatment to Secondary + Nitrification)

Additional information available to assess water quality changes is the biological data summarized on Figure C-29. The upper two figures show changes in species diversity and total number of taxa between 1974 and 1977. In general, slight improvements are observed in both indices. However, as is shown on Figure C-29, downstream indices are well below the index for the upstream station.

The bottom graph of Figure C-29 presents the number of fish species collected in the river in the summer of 1977. Although, un-ionized ammonia concentrations are noted to exceed suggested cold and warm water maximum concentrations of 0.02 and 0.05 mg/l, the observed data show a number of fish species living in the river. The number which averages about 10 species downstream of Lima, however, is less than the 22 species observed upstream of the pollutant inputs. It should also be noted that data collected in 1960 showed a total absence of fish in the river between Lima and the river mouth. This change in fish counts is not totally related to the AWT now in place at Lima, but is reflective of a decrease of pollution over the past two decades.

Within the framework of this study, no data were available to assess recreational changes associated with pollution reductions. In addition, although wasteload allocation modeling has been performed by the state of Ohio, it was not available within the framework of this project.

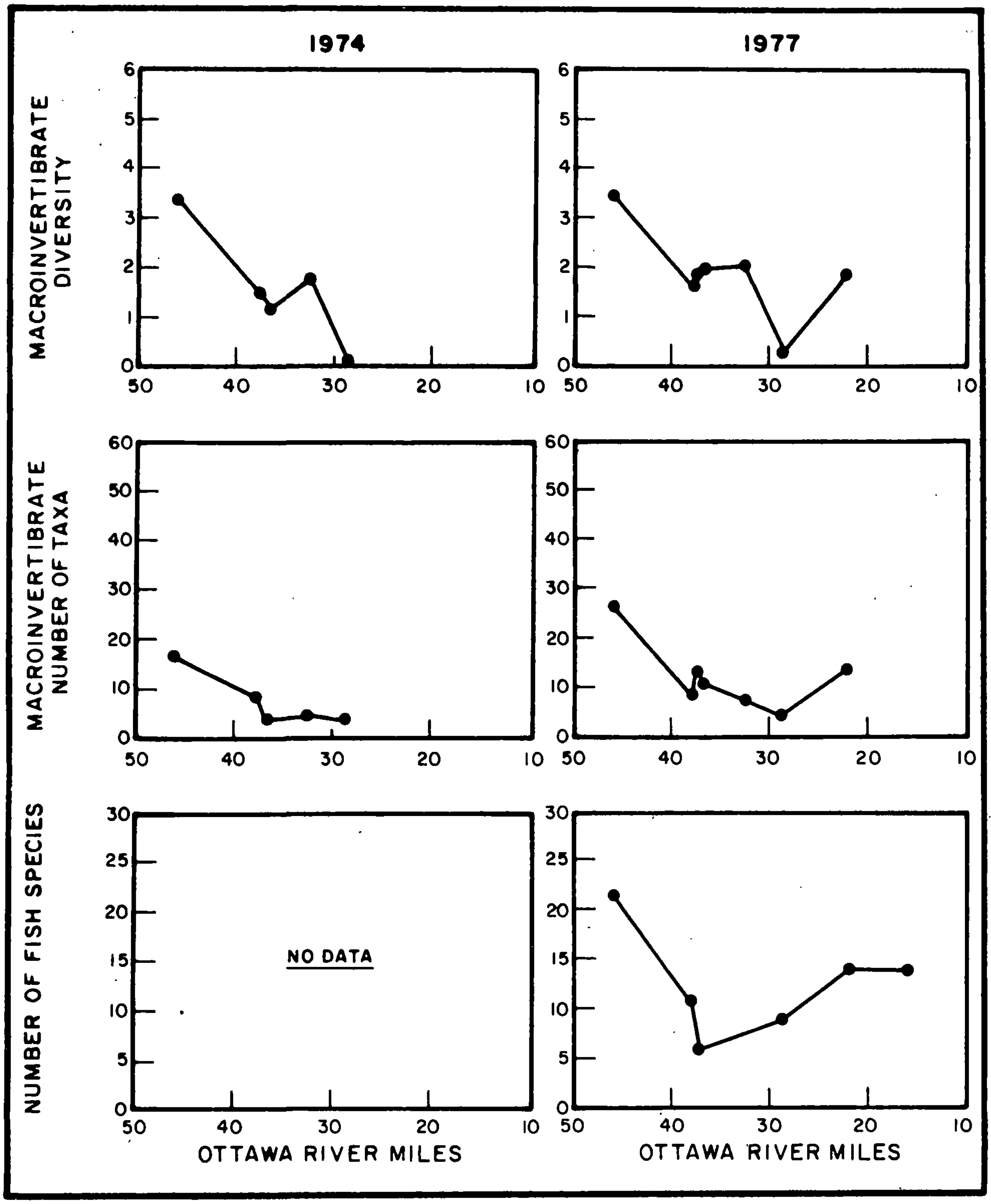


Figure C-29

Biology Comparisons for Ottawa River, Ohio

Project Case Study
Water Body: Bridge Creek, Wisconsin

Bridge Creek is a soft water trout stream located in southwestern Wisconsin. Since the creek does not flow towards either Lake Superior or Lake Michigan, waste treatment dischargers located on the creek are not subject to phosphorus removal as mandated by international agreements between the United States and Canada. Summer low flows in the creek are on the order of 10 cfs while the 7Q10 low flow is 2.6 cfs.

The main source of pollution on the creek is the Augusta POTW which in the pre-operative state was designed as a high rate trickling filter treatment facility. The Wisconsin Pollution Discharge Elimination System permit for this facility specified a maximum effluent BOD_5 concentration of 60.0 mg/l and no ammonia limitation. During a water quality survey conducted on August 21, 1978, this POTW had effluent BOD_5 and ammonia concentrations of 59.0 and 20.0 mg/l respectively.

Water quality data collected during this 1978 survey (Figure C-30) indicate an impact of the plant on creek dissolved oxygen, BOD_5, and ammonia concentrations. Un-ionized ammonia concentrations, however, did not exceed the suggested criteria. The wastewater treatment plant caused the dissolved oxygen to drop 1.5 mg/l, the BOD_5 to increase from 2.7 to 5.7 mg/l, and the ammonia to increase from 0.04 to 0.89 mg/l.

In June 1980, the new Augusta facility construction was completed and the plant came on line as an advanced secondary treatment plant utilizing Rotating Biological Contactor units. The plant was designed for seasonal treatment with summer effluent BOD_5 and ammonia limits at 30.0 and 16.0 mg/l and winter effluent limits at 45.0 and 32.0 mg/l (Figure C-31).

No detailed calibration analyses were performed in developing the effluent limitations stated above. The BOD_5 limitation was developed based on the "26 pound rule" (Reference 11, Section 6) and ammonia limitations were based on ammonia toxicity calculations for the protection of the cold water fishery at 7Q10 flows.

On August 26 to 27, 1981 an intensive water quality survey of Bridge Creek was conducted to evaluate water quality changes after the AST plant came on line. This survey was conducted at the same 10 cfs background flow and 17 to 20°C temperature as the pre-operative survey. Water quality data (Figure C-30) from this survey shows minor water quality improvements with respect to dissolved oxygen, BOD_5, and ammonia concentrations. Average stream oxygen levels increased about 14 percent and the maximum ammonia concentration decreased by 83 percent.

These improvements do not appear to be that significant compared to the changes in treatment levels. However, during both pre- and post-operative studies river flows were about four times the 7Q10. Had these surveys been conducted at a flow closer to the 7Q10, water quality changes may have been greater.

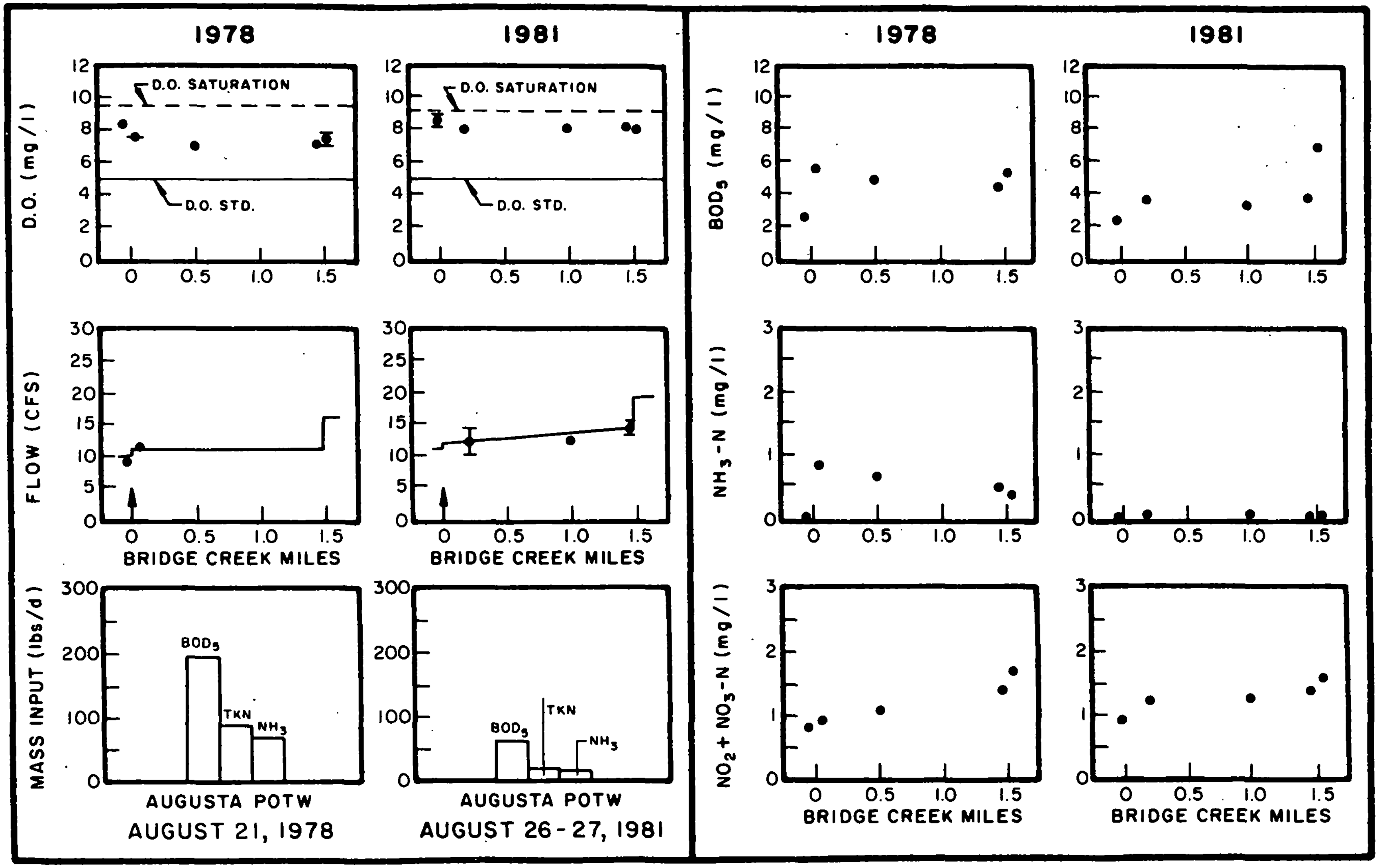


Figure C-30

Water Quality Comparisons for Bridge Creek, Wisconsin
(Secondary Treatment to Secondary + Nitrification)

Figure C-31

POST AUDIT FACT SHEET

NO. 10 WATER BODY NAME:	STREAM / RIVER / LAKE / ESTUARY	TRIBUTARY TO:	STATE:	MODEL USED TO MAKE WLA:
Bridge Creek	STREAM X	-	Wisconsin	YES ___ NO X

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH: 1 to 4 feet

APPROX. VELOCITY: 0.5 to 1.0 ft/sec

SLOPE: -

7Q10 FLOW: 2.6 cfs

	BEFORE Augusta POTW	BEFORE TOTAL	AFTER Augusta POTW	AFTER TOTAL	% CHANGE
POINT SOURCE DESIGN:					
FLOW (MGD) =	0.25	0.25	0.25	0.25	0%
BOD_5 (mg/l) / (lbs/d) =	60/(125)	125	30/(62)	62	- 50%
NH_3 (mg/l) / (lbs/d) =	-		16/(33)	33	-
COMMENT:	High Rate T.F.		RBC[1]		
POINT SOURCE OPERATING:		TOTAL		TOTAL	% CHANGE
FLOW (MGD) =	0.39	0.39	0.39[2]	0.39	0%
BOD_5 (mg/l) / (lbs/d) =	59/(191)	191	19.2/(62)	62	- 68%
NH_3 (mg/l) / (lbs/d) =	20/(65)	65	4.3/(14)	14	- 78%
COMMENT:					
RIVER CHEMISTRY:					
AVERAGE D.O. (mg/l) =	7.5		8.2		+ 9.3%
MINIMUM D.O. (mg/l) =	7.1		8.1		+14.1%
MAXIMUM BOD_5 (mg/l) =	5.6		6.8		+21.0%
MAXIMUM NH_3 (mg/l) =	0.9		0.15		-83.0%
MAX. UNIONIZED NH_3 (mg/l) =	0.004		0.0005		-87.5%

COMMENTS: 1. Rotating biological contact filters, designed for effluent ammonia of 16 mg/l summer and 32 mg/l winter; 2. Data not available, assumed equal to preoperative flow;

Further, Bridge Creek is a valuable recreational resource and is regularly used for fishing in the area downstream of the wastewater discharge. Although pre- and post-operative data indicates that a relatively small (less than 1.0 mg/l) improvement in dissolved oxygen ocurred, this improvement may be significant to the very sensitive and valuable fish that inhabit this stream. Additional data are needed to evaluate the biological and recreational changes.

Project Case Study
Water Body: Lemonweir Creek, Wisconsin

Lemonweir Creek is located in Monroe County in the southwestern part of the state of Wisconsin. The river does not flow towards either Lake Superior or Lake Michigan and therefore, is not subject to manditory phosphorus removal. The river is inpounded about a mile upstream of where the Tomah treatment works discharges treated effluent to the river.

Prior to November 1979, the Tomah POTW was a secondary treatment facility which had process units consisting of primary settling, trickling filters, activated sludge units, and secondary clarification. On August 22, 1978, a water quality survey was conducted in the stream to establish baseline water quality conditions prior to upgrading of the Tomah POTW. This survey (Figures C-32, C-33, C-34) indicated that river dissolved oxygen concentrations, both upstream and downstream of the POTW, were in violation of the dissolved oxygen standard of 5.0 mg/l. Downstream of the POTW inflow BOD_5 concentrations were elevated to 21.0 mg/l; ammonia concentrations were elevated to 6.9 mg/l; and un-ionized ammonia concentrations were as high as 0.083 mg/l.

By November 1979, the new treatment works came online with secondary treatment, nitrification, sand filtration, and effluent aeration. Summer effluent limitations were set by the state in 1976 for a maximum BOD_5 concentration of 10.0 mg/l and a maximum ammonia concentration of 4.0 mg/l. These limitations were preliminarily set using a simplified screening procedure called the "26 pound rule."

The new AWT facility was constructed and an August 1981 intensive water quality survey was conducted to assess the resulting change in water quality. This survey which was conducted at similar flow and temperature conditions to the 1978 survey, showed post-operative dissolved oxygen concentrations (Figure C-32) to be similar to concentrations which were observed in 1978. The observed data, however, do indicate that instream BOD_5, ammonia, and un-ionized ammonia concentrations in the stream are greatly reduced from the 1978 levels.

Additional dissolved oxygen data collected weekly for certain periods in 1978, 1979, 1980 and 1981 are also available to assess changes in stream water quality in response to the POTW upgrade. These data (Figure C-35) indicates a slight increase in the overall mean dissolved oxygen of 7.2 to 7.9 mg/l. The data, however, indicates a decrease in the summer mean from 5.0 to 2.1 mg/l. Although the data sets are sparce with respect to the post-operative data, it does seem to confirm the 1981 intensive dissolved oxygen data which indicates no noticeable oxygen improvements. The state is currently processing post-operative biological data for comparison with pre-operative data.

One conclusion that can be made here is that at the 1978 and 1981 conditions, upstream flow from the lake contained a large amount of suspended algae which were in the death phase, and respiration from these algae tended to drive the oxygen levels down. At either treatment level, oxygen consumption by

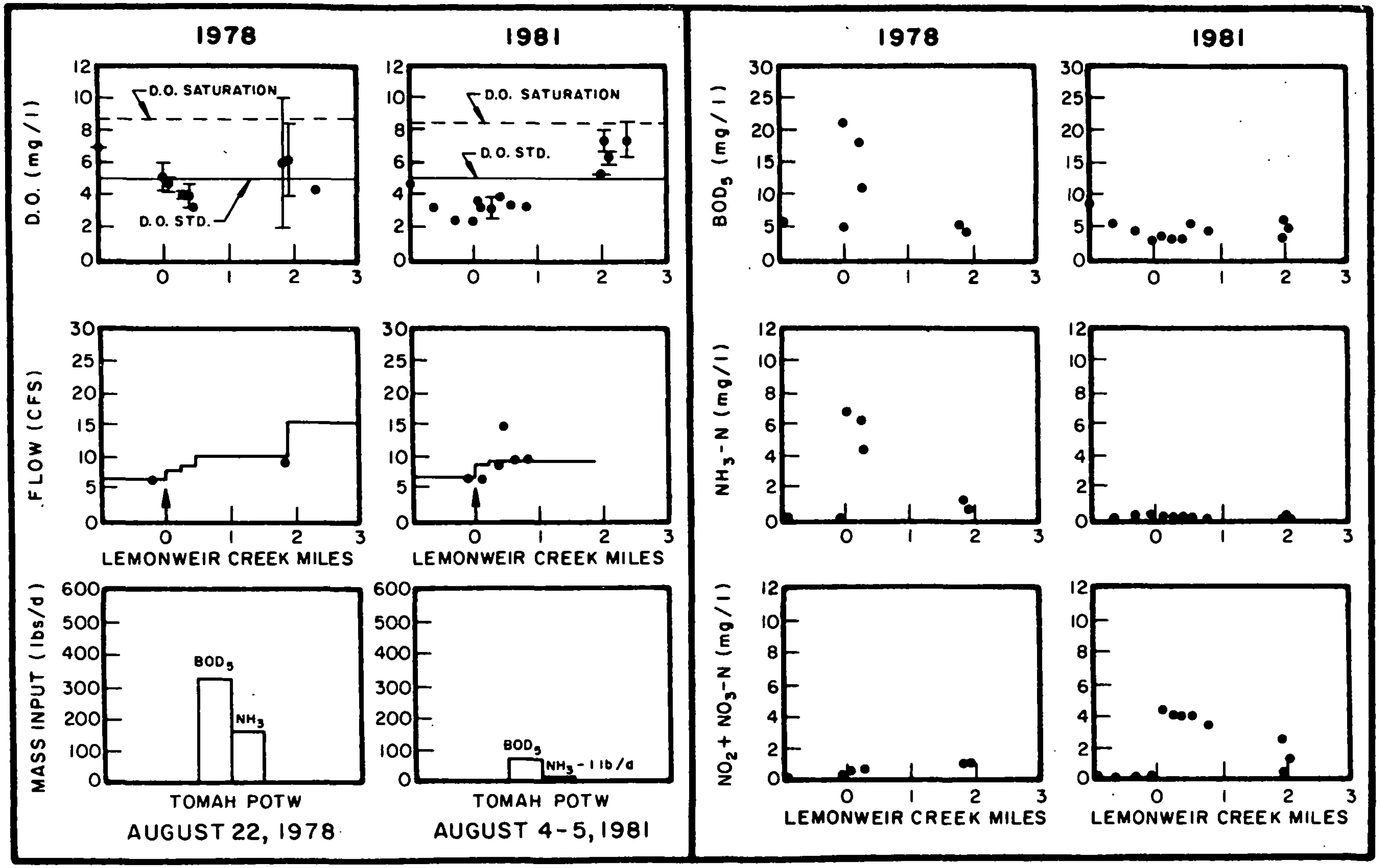


Figure C-32

Water Quality Comparisons for Lemonweir Creek, Wisconsin (Secondary Treatment to Secondary + Nitrification)

Figure C-33

POST AUDIT FACT SHEET

NO. 11 WATER BODY NAME:	STREAM / RIVER / LAKE / ESTUARY	TRIBUTARY TO:	STATE:	MODEL USED TO MAKE WLA:
Lemonweir Creek	STREAM X	-	Wisconsin	YES ___ NO X

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH: 1 to 2 feet

APPROX. VELOCITY: 0.2 ft/sec

SLOPE: N/A

7Q10 FLOW: 2.6 cfs

	BEFORE		AFTER		
POINT SOURCE DESIGN:	Tomah POTW	TOTAL	Tomah POTW	TOTAL	% CHANGE
FLOW (MGD) =	-		1.03	1.03	-
BOD_5 (mg/l) / (lbs/d)=	-		10.0/(83)	83	-
NH_3 (mg/l) / (lbs/d)=	-		4.0/(33)	33	-
COMMENT:	Sec.Treat. T.F.+Aeration		Tertiary Treat.[1]		
POINT SOURCE OPERATING:		TOTAL		TOTAL	% CHANGE
FLOW (MGD)=	1.0	1.0	1.5	1.5	+ 50.0%
BOD_5 (mg/l) / (lbs/d)=	43/(359)	359	6.0/(75)	75	- 79.0%
NH_3 (mg/l) / (lbs/d)=	21/(175)	175	<0.1/(1)	1	- 99.4%
COMMENT:					
RIVER CHEMISTRY:					
AVERAGE D.O. (mg/l)=	4.7		4.3		- 8.5%
MINIMUM D.O. (mg/l)=	2.1		1.7[2]		- 19.0%
MAXIMUM BOD_5 (mg/l)=	21.0		6.1[3]		- 71.0%
MAXIMUM NH_3 (mg/l)=	6.9		0.28[3]		- 96.0%
MAX. UNIONIZED NH_3 (mg/l)=	0.083		.0017[3]		- 98.0%

COMMENTS: 1. Sec. Treat. + air nitrification + filters; 2. Downstream of POTW, lower values observed upstream; 3. Downstream of POTW, higher values observed upstream;

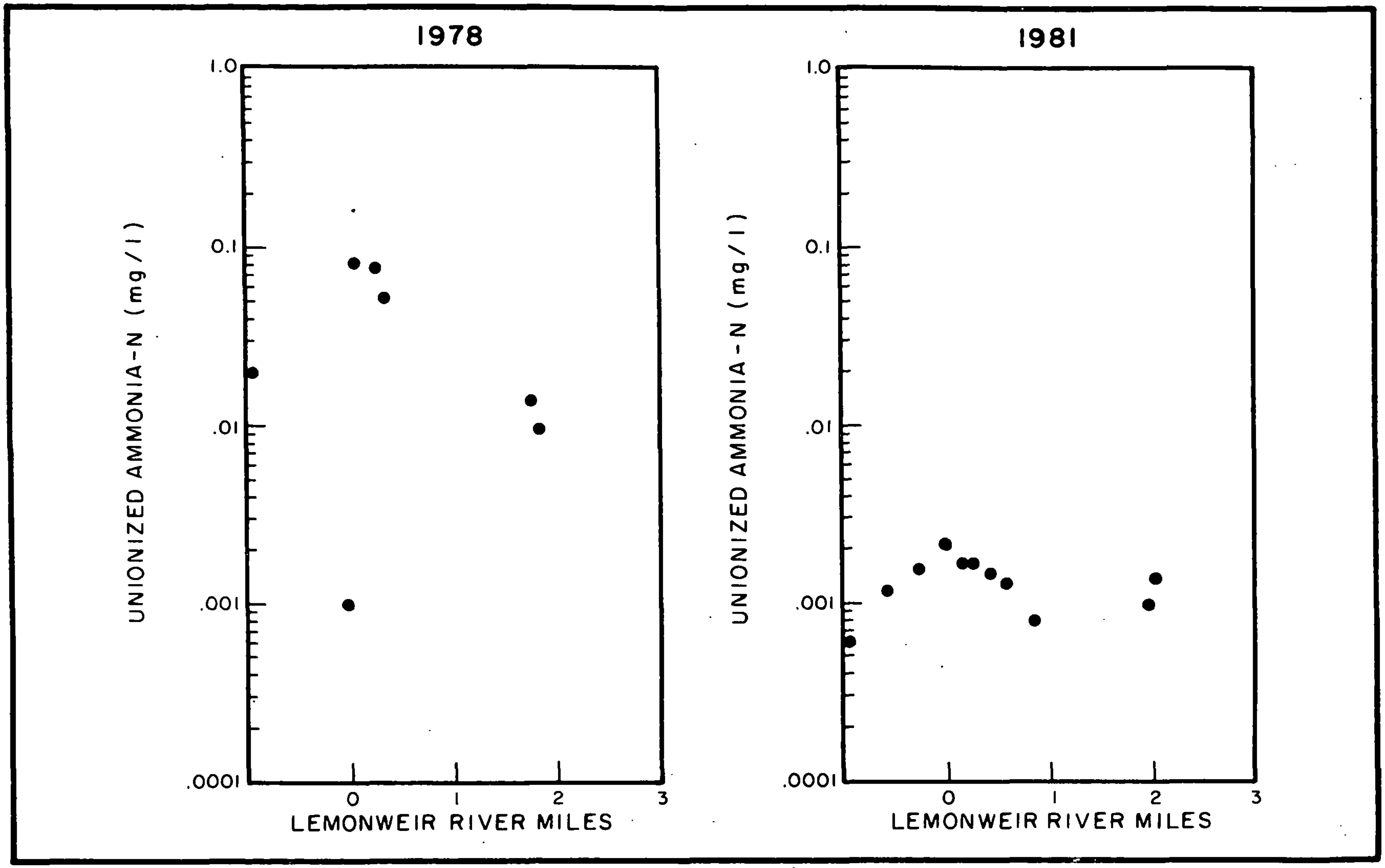
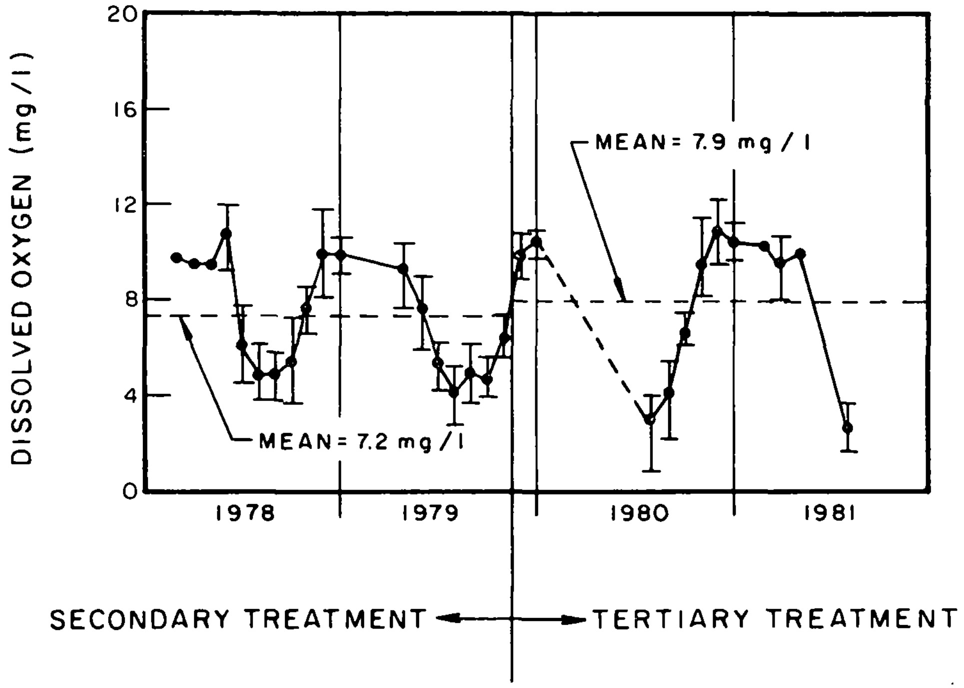


Figure C-34

Water Quality Comparisons for Lemonweir Creek, Wisconsin
(Secondary Treatment to Secondary + Nitrification)



JUNE, JULY, AUGUST & SEPTEMBER

	MEAN (mg/l)			STANDARD DEVIATION (mg/l)	
	BEFORE	AFTER	% CHANGE	BEFORE	AFTER
D.O.	5.0	2.1[1]	—[1]	4.4	2.0

1-POSTOPERATIONAL DATA BASED ON TO FEW SAMPLES TO BE ACCURATE

DATA SOURCE STORET

Figure C-35
Time History Data Analysis for Lemonweir River

materials discharged from the POTW did not significantly impact the total dissolved oxygen balance. At the 7Q10 flow this conclusion would tend to change and the POTW impact may tend to be more significant.

Project Case Study
Water Body: Cibolo Creek,

Cibolo Creek is located in the state of Texas just north of the city of San Antonio. The river flows in a south easterly direction. From the city of Schertz, the river traverses about 75 miles and joins the San Antonio River.

Upstream of Schertz, the river passes through an aquifer recharge zone during which time the flow is essentially reduced to zero. The base flow downstream of Schertz is formed by wastewater effluents discharged to the river by the Universal City POTW, Randolf Air Force Base (AFB) wastewater treatment facility and the city of Schertz POTW. The river flow is comprised totally of wastewater flow for the 10 mile reach downstream of Schertz. River depth in this reach is about one foot or less while velocities are less than 0.1 feet per second.

In 1974 and 1975, all discharges to the river near Schertz were operating as secondary treatment facilities. Effluent BOD_5 concentrations from these facilities were less than 20.0 mg/l and both the Randolf AFB and the Schertz treatment works were at times achieving a degree of inplant nitrification. Water quality data collected (Figure C-36) in 1975 indicate depressed dissolved oxygen concentrations near Schertz (1.4 mg/l), elevated CBOD levels (9.0 mg/l) and elevated ammonia-N concentrations (11.4 mg/l).

Shortly after this survey, a new treatment facility was constructed. This POTW accepts the flow from the old Schertz POTW , the Universal City POTW, and Randolf AFB. The new plant is a trickling filter treatment facility (Figure C-37).

In 1978, the state of Texas issued a report in which wasteload allocations were developed for this river segment. A version of the QUAL model similar to WRE/QUAL II was used in this evaluation. The model which was calibrated against the December 1975 water quality data, was used to make wasteload allocations at temperatures of 28^{o}C and a one in two year 7 day low flow upstream of Schertz of zero cubic feet per second. The allocations show that at a 1995 flow of 5.82 mgd from the ODO J. Riedal POTW (new Schertz facility) effluent BOD_5 and NH_3 concentrations of 5.0 and 2 mg/l respectively, would still result in river minimum dissolved oxygen concentrations of less than 3.0 mg/l. However, because of the preliminary nature of the modeling and the inadequate data available for model calibration, the authors recommended a permit be written at BOD_5 of 10.0 mg/l and no ammonia limitation. Further, they recommended additional field studies be conducted to collect data necessary for a more refined modeling analysis.

These additional data were collected in April, May and June of 1980. Water quality data were collected in April, while time of travel, reaeration, and BOD oxidation rate information were gathered in May and June. These water quality data presented on Figure C-36, show sampling stations which are located to give much better definition of water quality gradients and the dissolved oxygen sag. The data however, do not show substantial improvements in quality beyond the

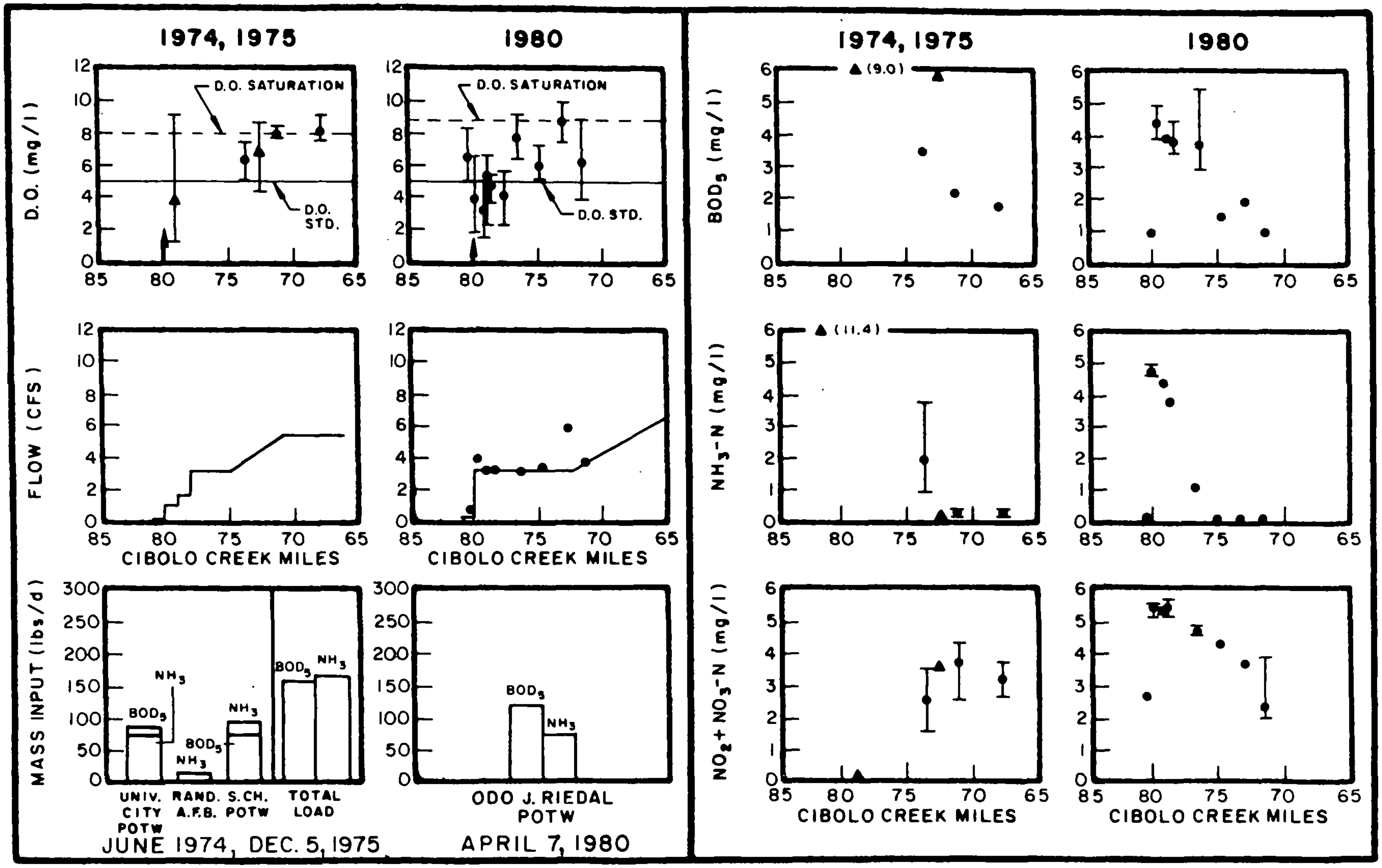


Figure C-36

Water Quality Comparisons for Cibolo Creek, Texas
(Old Secondary Facility to New Secondary Facility)

Figure C-37

POST AUDIT FACT SHEET

NO. 12 WATER BODY NAME: Cibolo Creek	STREAM X / RIVER / LAKE / ESTUARY	TRIBUTARY TO: San Antonio River	STATE: Texas	MODEL USED TO MAKE WLA: YES X NO

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH= 0.5 to 1.0 feet

APPROX. VELOCITY= less than 0.1 cfs

SLOPE= N/A

7Q10 FLOW=[1] less than 0.1 cfs

	BEFORE[2]				AFTER		% CHANGE
POINT SOURCE DESIGN:	Universal City POTW	Randolf AFB	Shertz POTW	TOTAL	ODO J. Riedal POTW	TOTAL	% CHANGE
FLOW (MGD) =				2.2	3.2		
BOD_5 (mg/l) / (lbs/d)=				27	10		
NH_3 (mg/l) / (lbs/d)=				-	-		
COMMENT:							
POINT SOURCE OPERATING:				TOTAL		TOTAL	% CHANGE
FLOW (MGD)=	0.59	0.37	0.95	1.9	2	2	+ 5%
BOD_5 (mg/l) / (lbs/d)=	15.5/(76)	4.7(15)	8.7(169)	160	7.3/(122)	122	- 24%
NH_3 (mg/l) / (lbs/d)=	14.2/(70)	1.2/(4)	11.4/(90)	164	4.8/(80)	80	- 51%
COMMENT:	All at Secondary Treatment[3]				Secondary Treatment[4]		
RIVER CHEMISTRY:							
AVERAGE D.O. (mg/l)=	-				6.0		-
MINIMUM D.O. (mg/l)=	1.4				1.6		+14.2%
MAXIMUM BOD_5 (mg/l)=	-				5.5		-
MAXIMUM NH_3 (mg/l)=	11.4				5.0		- 55%
MAX. UNIONIZED NH_3 (mg/l)=	1.03				0.031		- 97%

COMMENTS: 1. Upstream of point sources, actually 7Q2; 2. Permit requirements; 3. Effluent data shows Randolf AFB and Schertz were achieving partial nitrification; 4. Trickling filter plant but achieving partial nitrification;

original 1974, 1975 quality data. This is in line with the fact that the new facility does not substantially reduce effluent loads to the stream. The data do indicate depressed water quality conditions which can be at least in part caused by effluents discharged by the ODO J. Riedel POTW.

A post-audit simulation presented on Figure C-38 shows that the model under predicts dissolved oxygen impacts downstream of the ODO J. Riedal POTW. Observed daily average minimum dissolved oxygen concentrations from the 1980 data set are near 3.0 mg/l while the model predicts a minimum dissolved oxygen of near 4.5 mg/l. Further, because of model inadequacies and variations in observed data, the post-audit model simulation has a RMS error of approximately 1.9 mg/l when compared to the 1980 dissolved oxygen data. Because of unexplained spatial dissolved oxygen variations it will probably not be possible to reduce the error substantially. At the time of this writing, the state of Texas has not completed its revisions to the model and have not developed a revised wasteload allocation.

POST AUDIT MODEL FACT SHEET

WATER BODY NAME: CIBOLO CREEK, TEXAS

MODEL TYPE: FINITE SEGMENT — **CALIBRATED:** YES X NO ___

MODEL NAME: WRE EXPANDED VERSION QUAL I (SIMILAR TO WRE QUAL II) — **VALIDATED:** YES ___ NO X

WASTE LOAD ALLOCATION

RIVER FLOW:[1] 0 CFS

RIVER TEMP: 28°C

POINT SOURCE INFO:

ODO J. RIEDAL

Q (MGD) = 5.82

BOD_5 (mg/l) = 5.0

NH_3 (mg/l) = 2.0

UPSTREAM INFO:

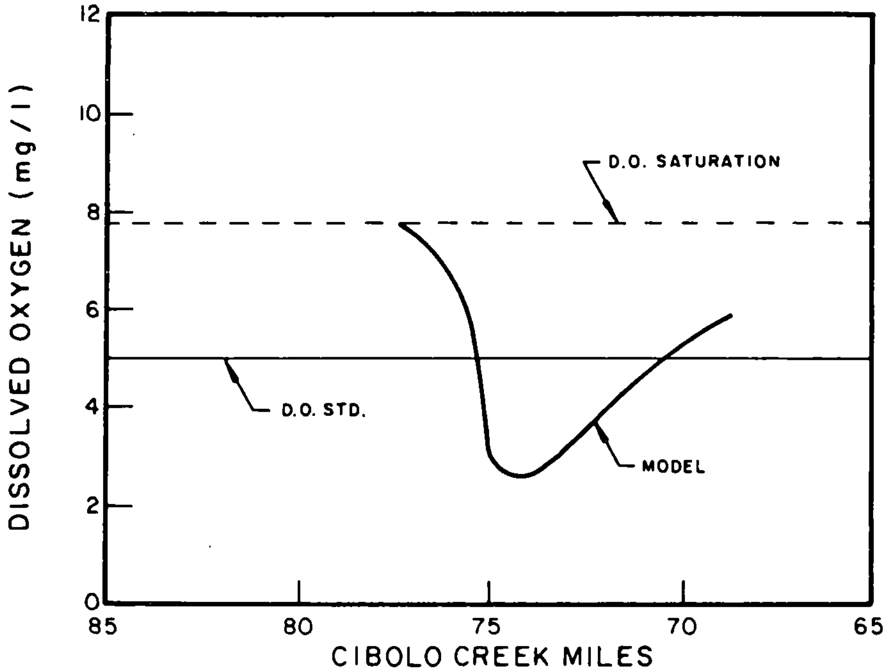
Q (CFS) = 0

BOD_5 (mg/l) = —

NH_3 (mg/l) = —

COMMENTS:

1 NO UPSTREAM OF POTW



POST AUDIT

RIVER FLOW: 0.5 CFS

RIVER TEMP: 20°C

POINT SOURCE INFO:

ODO J. RIEDAL

Q (MGD) = 2.0

BOD_5 (mg/l) = 7.3

NH_3 (mg/l) = 4.8

UPSTREAM INFO:

Q (CFS) = 0.5

BOD_5 (mg/l) = 1.0

NH_3 (mg/l) = 0.0

COMMENTS:

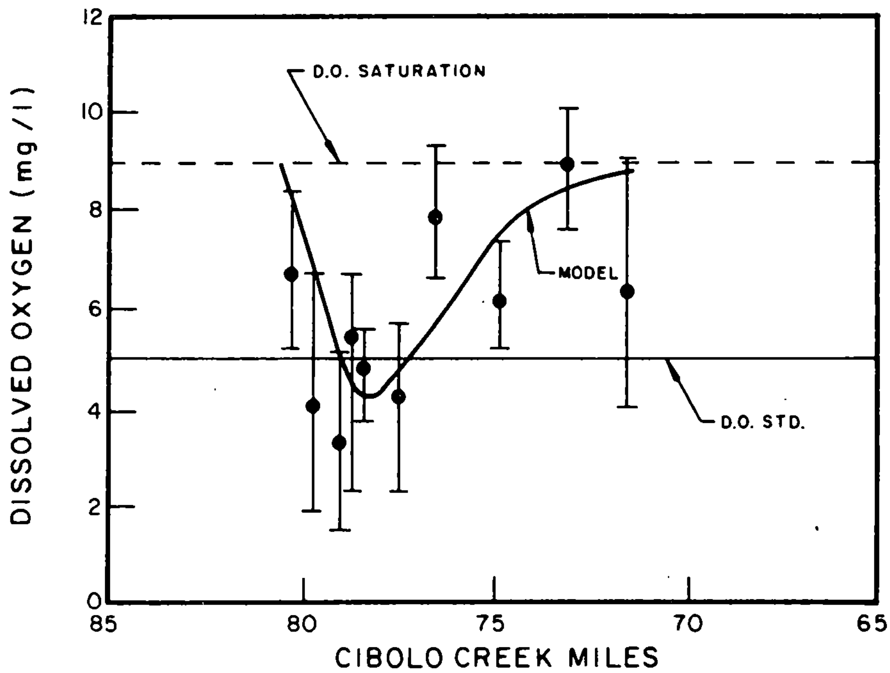


Figure C-38

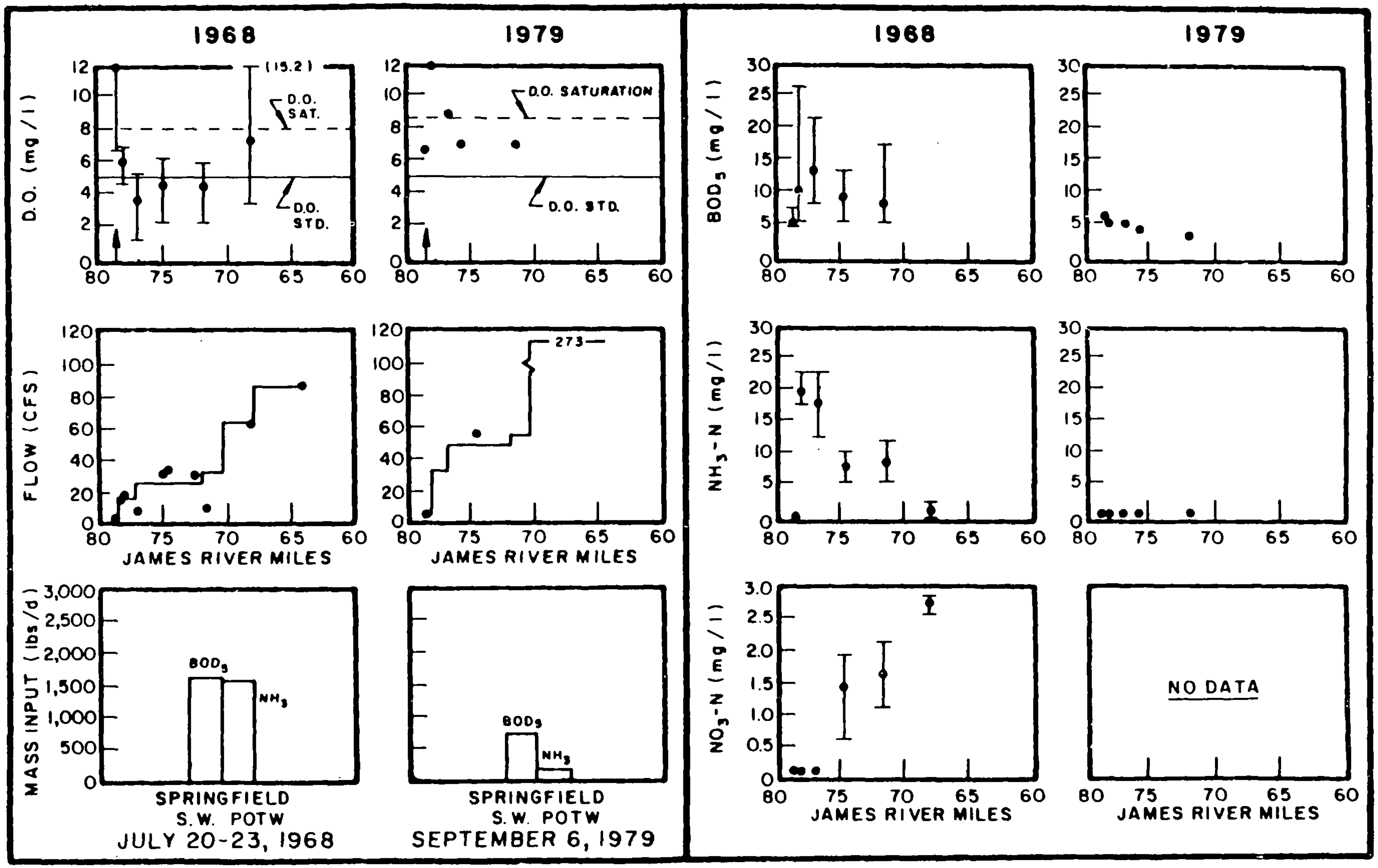


Figure C-39

Water Quality Comparisons for Wilsons Creek, Missouri (Secondary Treatment to Sec. + Nitrif. + Filters)

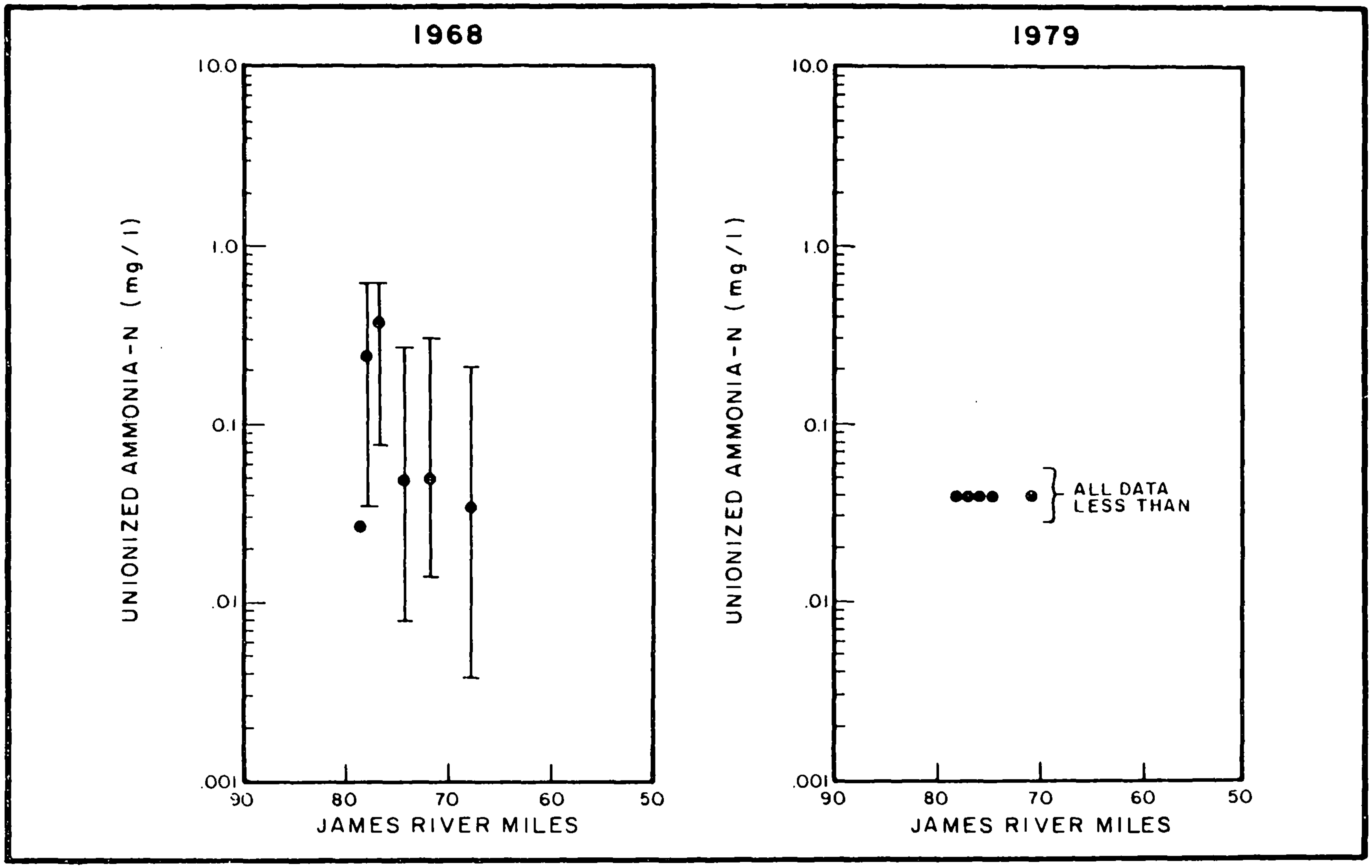


Figure C-40

Water Quality Comparisons for Wilsons Creek, Missouri
(Secondary Treatment to Sec. + Nitrif. + Filters)

Project Case Study
Water Body: Wilsons Creek, Missouri

Wilsons Creek located in southwestern Missouri drains about 84 square miles of land in and including the city of Springfield. The average elevation of the basin is about 1250 feet above mean sea level and the river slope averages about 7.3 feet per mile. Summer low flow in Wilson Creek can be as low as one cubic foot per second. A few miles downstream of Springfield, Wilsons Creek joins the James River. The combined flows of the James River and Wilsons Creek flow south for 70 miles and enter a reservoir system near the Missouri-Arkansas border.

At summer dry flow, the effluent from the Springfield Southwest Sewage Treatment Plant accounts for almost 100 percent of the stream flow in Wilsons Creek. In 1954, 1960, 1966, 1971, 1975 and 1976, fish kills which occurred in Wilsons Creek and the James River, were associated with wastewaters discharged from the sewage treatment facility.

An intensive water quality study (Figures C-39, C-40) performed in 1968 in Wilsons Creek showed dissolved oxygen levels of 1.2 mg/l, BOD_5 concentrations of 26.0 mg/l, and ammonia-N of 23.0 mg/l. In addition, un-ionized ammonia concentrations during this time were 0.8 mg/l downstream of the Springfield Southwest Sewage Treatment Plant. During this survey, the sewage treatment plant was an activated sludge secondary treatment plant with effluent BOD_5 and ammonia-N concentrations averaging about 20.0 mg/l (Figure C-41).

In 1973, consultants for the city of Springfield submitted plans for construction of an AWT facility at the site of the old secondary plant. A wasteload allocation study for the AWT plant was developed in January 1975. As part of this study, model RIVER was calibrated against the 1968 intensive survey data. Subsequent wasteload allocations performed at low flow conditions, showed that a tertiary treatment plant with an effluent BOD_5 of 10.0 mg/l and an effluent ammonia of 1.0 mg/l would comply with river dissolved oxygen and ammonia water quality standards.

An AWT facility was approved for construction and became operational in October 1977. A subsequent intensive water quality study conducted by the city of Springfield in 1979 showed substantially improved dissolved oxygen, BOD_5, ammonia and un-ionized ammonia levels in the stream (Figures C-39, C-40). Further, weekly sampling performed by the USGS at Boaz, Missouri on the James River just downstream of the Wilsons Creek inflow, show substantial improvement in oxygen and ammonia levels. Before installation of the new facility, summer oxygen concentrations averaged 4.7 mg/l (Figure C-42). After the plant became operational, summer mean dissolved oxygen concentrations increased to 7.0 mg/l.

Biological improvements were also observed. Generally, fishing has been improved as seen by appearance of large and small mouth bass. Schools of small fish have also been observed in Wilsons Creek just downstream of the outfall. Improved water quality has lead to increased use of Wilsons Creek National Battlefield Park which has recently undergone a major expansion. Macroinvertebrate surveys conducted in 1964 to 1965 and 1980 have also shown improvements.

Figure C-41

POST AUDIT FACT SHEET

NO. 13 WATER BODY NAME:	STREAM X / RIVER / LAKE / ESTUARY	TRIBUTARY TO:	STATE:	MODEL USED TO MAKE WLA: YES X NO
Wilsons Creek	STREAM	James River	Missouri	YES

PHYSICAL CONDITIONS

STREAM, RIVER, ESTUARY:

AVERAGE DEPTH= 1.0 feet

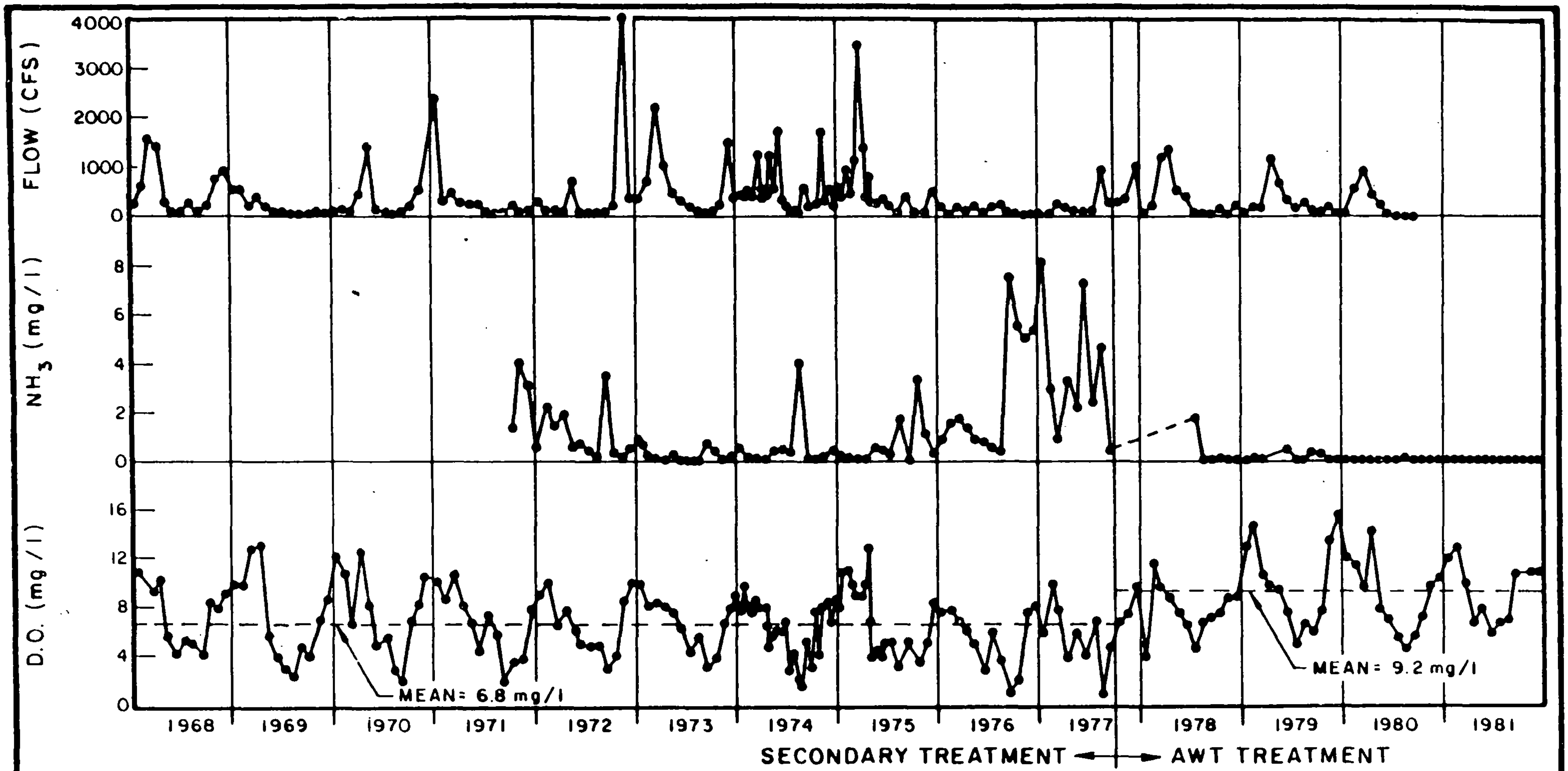
APPROX. VELOCITY= 0.75 ft/sec

SLOPE= 4 to 12 ft/mile

7Q10 FLOW= 8 cfs + POTW flow

	BEFORE: Springfield S.W. POTW	BEFORE:	BEFORE: TOTAL	AFTER: Springfield S.W. POTW	AFTER:	AFTER: TOTAL	% CHANGE
POINT SOURCE DESIGN:							
FLOW (MGD) =	20[2]						+ 50%
BOD_5 (mg/l) / (lbs/d)=	30/(5064)			10/(2520)			- 50%
NH_3 (mg/l) / (lbs/d)=	-			1/(250)			-
COMMENT:	Sec.Treat. Act. Sludge			See Note 1			
POINT SOURCE OPERATING:			TOTAL			TOTAL	% CHANGE
FLOW (MGD)=	9.1[3]			24.7			+ 171%
BOD_5 (mg/l) / (lbs/d)=	21.5/(1632)			3.6/(742)			- 55%
NH_3 (mg/l) / (lbs/d)=	20.8/(1579)			1.5/(309)			- 80%
COMMENT:				5/79-6/80 data			
RIVER CHEMISTRY:							
AVERAGE D.O. (mg/l)=		6.4			8.2		+ 28.1%
MINIMUM D.O. (mg/l)=		1.4			6.5		+364.3%
MAXIMUM BOD_5 (mg/l)=		26.0			5.0		- 80.8%
MAXIMUM NH_3 (mg/l)=		22.2			<1.0		- 95.5%
MAX. UNIONIZED NH_3 (mg/l)=		0.61			<0.04		- 93.4%

COMMENTS: 1. Secondary + air nitrification + ozone + filter (average conditions); 2. A portion of effluent is discharged into another river; 3. Discharged to Wilsons Creek.



JUNE, JULY, AUGUST & SEPTEMBER

	MEAN (mg/l)			STANDARD DEVIATION (mg/l)	
	BEFORE	AFTER	% CHANGE	BEFORE	AFTER
FLOW[1]	276	232	−16%	336	202
D.O.	4.7	7.0	+49%	1.6	1.5
NH_3	1.4	0.25	−82%	2.1	0.44

1-UNITS = CFS

DATA SOURCE STORET

Figure C-42
Time History Data Analysis for Wilsons Creek
(Station Code: 07052250 · Agency Code: 112WRD)

These data (Figure C-43) show an increase in the number of taxa downstream of the facility. The data also show a shift from tolerant species to intolerant species.

In the 1975 analyses, model RIVER was calibrated against the 1968 intensive water quality data. The model was then used to evaluate future water quality at critical flow and temperature for the proposed treatment upgrade of nitrogen removal and effluent polishing. The wasteload allocation shown on Figure C-44 indicated increased treatment would substantially improve dissolved oxygen levels. In the present analysis, the calibrated model was tested by calculating the post-audit instream water quality data. The results of this test, also shown on Figure C-44, indicate that the model does simulate the water quality data with a high degree of accuracy. It is interesting to note that after upgraded treatment, the POTW effluent dissolved oxygen concentration was 15.0 to 20.0 mg/l due to pure oxygen activated sludge treatment and disinfection by ozonation. As shown in the post-figure, the model was capable of accurately calculating the effect of the high effluent dissolved oxygen on river oxygen levels.

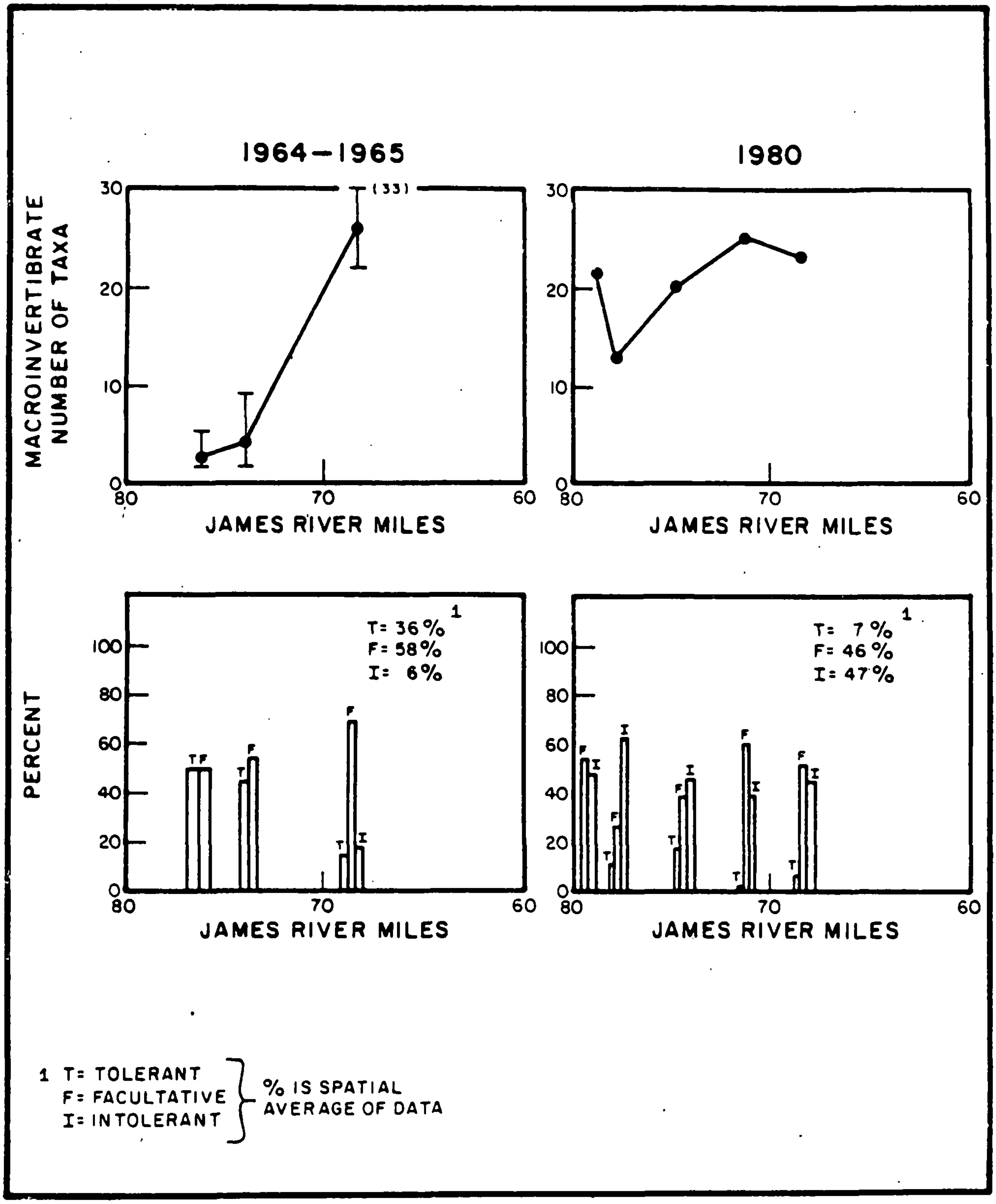


Figure C-43

Biology Comparisons for Wilsons Creek, Missouri

POST AUDIT MODEL FACT SHEET

WATER BODY NAME: WILSONS CREEK, MISSOURI

MODEL TYPE: STREETER-PHELPS **CALIBRATED:** YES X NO ___
MODEL NAME: RIVER (HYDROSCIENCE) **VALIDATED:** YES ___ NO X

WASTE LOAD ALLOCATION

RIVER FLOW:[1] 5.4 CFS
RIVER TEMP: 25°C

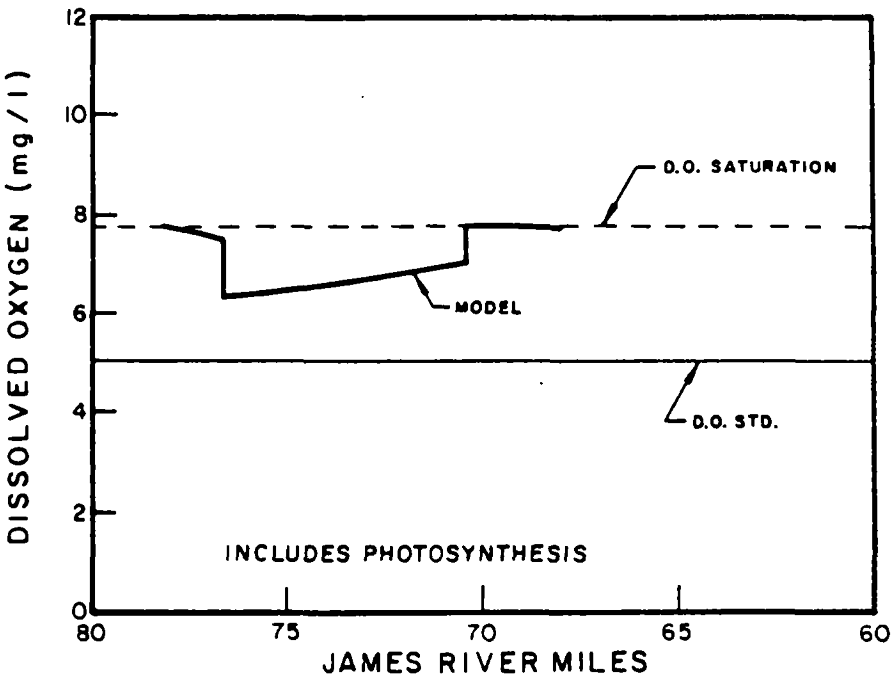
POINT SOURCE INFO: SPRINGFIELD S.W. - POTW

Q (MGD) = 19.0
BOD_5 (mg/l) = 10.0
NH_3 (mg/l) = 1.0

UPSTREAM INFO:

Q (CFS) = 0
BOD_5 (mg/l) = —
NH_3 (mg/l) = —

COMMENTS:
1 UPSTREAM OF POTW



POST AUDIT

RIVER FLOW:[1] 0 CFS
RIVER TEMP: 22.8°C

POINT SOURCE INFO: SPRINGFIELD S.W. - POTW

Q (MGD) = 17.0
BOD_5 (mg/l) = 5.0
NH_3 (mg/l) = 1.0

UPSTREAM INFO:

Q (CFS) = 5.8
BOD_5 (mg/l) = 5.0
NH_3 (mg/l) = 0.9

COMMENTS:
POTW EFFLUENT D.O. APPROX. 14 mg/l BECAUSE OF OZONE DISINFECTION AND PURE-OX TREATMENT

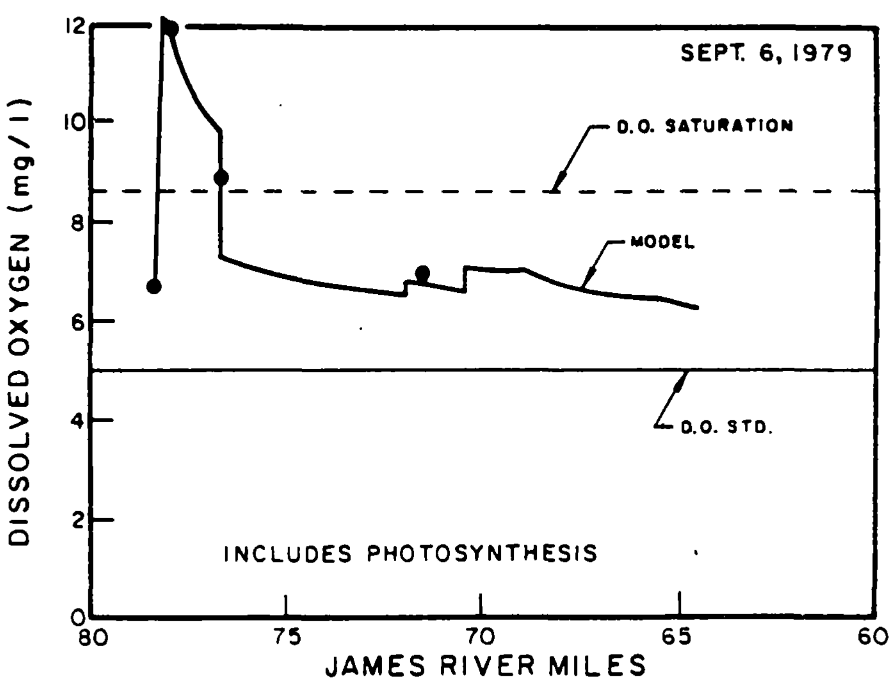


Figure C-44