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Research and Development

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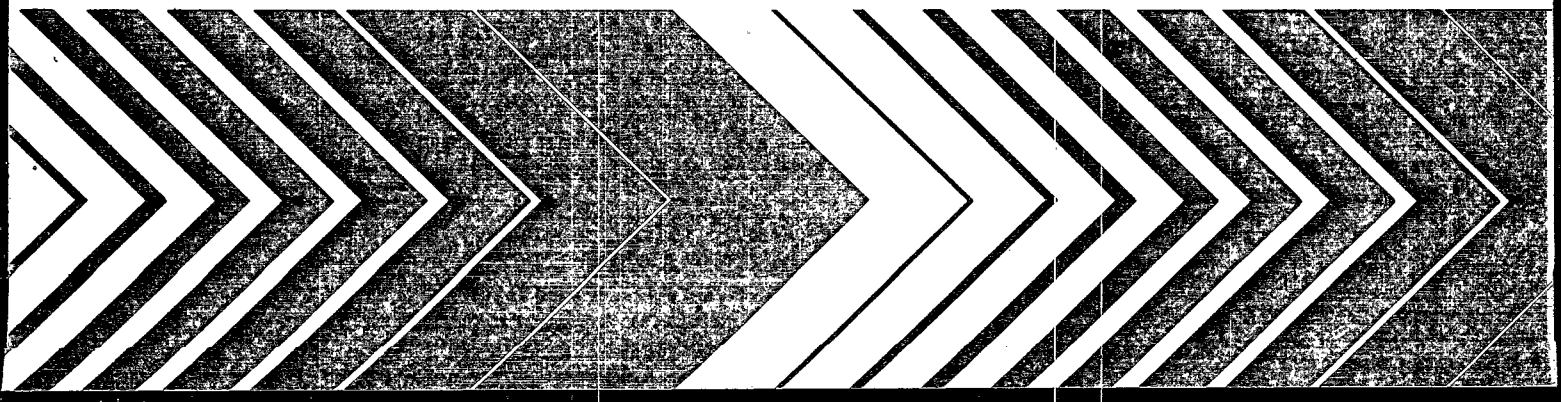
Dissolved Oxygen Measurements in Ohio Streams Following Urban Runoff



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EPA-600/2-80-092
July 1980

DISSOLVED OXYGEN MEASUREMENTS IN OHIO STREAMS FOLLOWING URBAN RUNOFF

by

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Grant No. R805201-01

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report describes the results of a short term screening project designed to identify potential stream sites in the State of Ohio at which more detailed studies of the impact of urban runoff on dissolved oxygen could be undertaken.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

ABSTRACT

This short-term research project was undertaken to locate and identify sites where potential dissolved oxygen (D.O.) impacts exist during periods of urban runoff, and to provide the necessary information to justify more extensive verification studies at the impacted sites. Since few field data are available on the effects of urban runoff on D.O. in receiving waters, this study was designed as a rough screening project to aid in selecting sites for in-depth study.

Thirteen Ohio towns and cities situated on streams and rivers with different average monthly flow rates were investigated during the spring and summer of 1977 to determine their suitability as sites for more extensive field studies dealing with the pollution of receiving waters from the discharge of combined sewer overflows. The criteria used for these determinations included: (1) the results of field measurements of the D.O. concentrations in the receiving streams below the towns following a discharge from the combined sewer outfalls; (2) an evaluation of the accessibility of suitable sampling locations along the receiving streams; (3) an inventory of the stream and precipitation gaging stations near the town; and (4) the availability of other information related to the combined sewer system in the town. Cities and towns evaluated during this study included Akron, Bucyrus, Delphos, Findlay, Lancaster, Lima, Newark, Norwalk, Tiffin, Upper Sandusky, Wapakoneta, Washington Court House and Wooster.

Study results indicated that the majority of the towns investigated were not suitable locations for conducting more extensive field studies. Several communities were rejected because poor quality effluents from municipal sewage treatment plants, industrial operations, or natural sources masked the impacts that the combined sewer discharges had on the D.O. resources of the receiving streams. Sites were also rejected because either the combined sewer system or the stream drainage pattern was too complex to monitor. Other sites were eliminated because the combined sewer discharges did not decrease the D.O. levels to less than 5 mg/l.

Only Lancaster, Newark, and Wapakoneta sastisfactorily met the criteria established to qualify them as suitable locations for more extensive field studies on the impacts of combined sewer discharges on receiving streams.

This report was submitted in fulfillment of Grant No. R805201-01 by the Water Resources Center at the Ohio State University under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period March 1977 to September 1977, and work was completed as of December 1978.

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ACKNOWLEDGEMENTS

The cooperation of the superintendents of the municipal wastewater treatment plants in all of the 13 towns and cities included in this study, and of their staffs and their supervisors, is gratefully acknowledged and deeply appreciated. My appreciation is also extended to Dr. David Baker, Director of the River Laboratory at Heidelberg College, Tiffin, Ohio; Dr. Kenneth R. Smith of the Zoology Department of the Lima Campus of the Ohio State University; and Professor Tommy L. Zimmerman of the Agricultural Technical College of the Ohio State University at Wooster for their help in supervising the field crews.

My sincerest thanks go to members of the field crew, and particularly to Tom Tiefert, who were ready to sample streams at any hour of the night or day, and generally under the most trying weather conditions.

SECTION 1

INTRODUCTION

There is limited nationally verified data on the environmental impacts of urban stormwater runoff on receiving waters. Impact data is needed to determine the degree of pollution in receiving waters caused during wet weather discharges particularly discharges from urban combined sewered areas. Priority should be given to sites that show a potential for a dissolved oxygen (D.O.) sag to occur as a result of combined sewer overflows (CSOs), and have receiving water characteristics that will enable field verification of unsteady state water quality prediction models.

The objective of this study was to locate and screen sites suitable for in-depth field monitoring studies to determine the D.O. impact of CSOs on receiving waters. The data collected during these proposed future in-depth field studies would be used for verifying and calibrating unsteady state water quality prediction models. The method used to select suitable sites was to first locate communities with combined sewer systems and then to measure changes in downstream D.O. concentration during periods of dry weather, during rainfalls, and shortly after rainfall periods. It was anticipated that D.O. sags would develop as a result of these combined sewer discharges and the relative magnitude of these sags would be used in evaluating the most suitable sites for the in-depth studies.

The selection of suitable sites for the field studies in this type of activity is of obvious importance. Municipalities under consideration must have combined sewers that overflow periodically to the receiving streams, and the wastes generated must have measurable impacts on the quality of these waters. Since these impacts vary with time and with distance along the stream, accessibility to suitable sampling locations above and below the discharge points must be evaluated. Stream gaging stations and past records of stream flow should be available. The cooperation of the local officials, particularly the operators of the municipal wastewater treatment facilities, is invaluable in any study of this type; for frequently these individuals are the people with the most current knowledge of the local sewer system and its operation.

To attain the objective of this study, towns of different sizes, discharging combined sewer effluents to receiving streams having different mean daily flow rates, were evaluated during the spring and summer of 1977 to determine: 1) if the combined sewer overflows from these towns had a measurable D.O. impact on the quality of water downstream of the town; 2) if there were adequate sampling sites above and below the combined sewer

outlets in the town with good accessibility to conduct an impact study; 3) if other sources of information including stream flow records, precipitation records, engineering reports and unpublished data on the impacts of combined sewer overflows for the streams were available; and 4) the number and extent of point wastewater discharges from municipal and industrial facilities.

The only criterion used to determine the impact of the discharge of combined sewer overflows from these towns was the D.O. levels in the streams below the towns. Other information related to the towns and to the suitability of sampling locations was obtained from personal contacts with the officials of the towns, the Ohio Environmental Protection Agency, the United States Geological Survey District Office in Columbus, Ohio and the Ohio Department of Natural Resources. Much information was also determined during site visits made prior to and during the field sampling program.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The results of the survey of thirteen towns and cities throughout northern and central Ohio to select those best suited as possible sites for more extensive field projects to determine the D.O. impacts that combined sewer discharges from these communities have on their receiving waters indicated that Lancaster, Newark and Wapakoneta would be good candidate locations.

Akron and Norwalk should not be considered because the stream drainage systems at these locations are too complex for analysis. Bucyrus, Delphos, Findlay, Washington Court House and Wooster should be eliminated as candidate locations because wastewater from non-point, industrial and/or municipal sources in these communities tend to mask the impacts that combined sewer discharges have on their receiving streams. Lima is currently constructing an interceptor/storage system to control its combined sewer overflows, and the combined sewer discharges from Tiffin and Upper Sandusky do not exert a significant enough impact on the receiving streams at these locations to warrant further studies.

SECTION 3

METHODOLOGY

INTRODUCTION

Thirteen towns and cities in Ohio, situated on streams and rivers having different mean daily flow rates, were investigated to determine their suitability as sites for more extensive field studies dealing with the pollution of receiving waters from the discharge of combined sewer overflows. The evidence used for this determination included:

measurements of the D.O. levels in the receiving waters downstream of the towns following a discharge from the combined sewer outfalls in the towns;

an assessment of the accessibility of sampling sites available for these measurements above and below the towns;

an inventory of the stream and precipitation gaging stations in the vicinity of the town, and the availability of the records for these stations; and,

a listing of other sources of data related to the impact of the combined sewer discharges on the receiving streams in both published and unpublished forms.

PRELIMINARY SITE SELECTION

Twelve towns and cities in the northern and central portions of Ohio were initially considered for this study. Later, the town of Washington Court House was added to the list of towns to be investigated. All thirteen of the communities had combined sewers; and their sizes, as reflected by their 1970 populations, ranged between 5,645 and 275,425 people. The mean daily flows during the 1977 water year for the receiving streams below these towns as reported in the United States Geological Survey Water Data Reports OH-77-1 and OH-77-2 ranged between 1.8 and 11.4 cubic meters per second (64 and 404 cubic feet per second).

The population and mean stream flow data for the cities and receiving streams considered in this study are shown in Table 1. These data are presented so that the relative sizes of the towns and the receiving streams can be compared. Stream gaging stations are not in operation at all of these sites; and, in several instances, the flow data for the nearest gaging

station downstream of the town are shown in the table.

TABLE 1. OHIO CITIES FOR DISSOLVED OXYGEN SURVEY

Town	Population 1970	Principal receiving stream	Mean daily flow water year 1977 m^3/s	cfs
Akron	275,425	Cuyahoga River	11.3	401
Bucyrus	13,111	Sandusky River	1.8	64
Delphos	7,608	Jennings Creek (a)	-	-
Findlay	35,800	Blanchard River	4.2	150
Lancaster	32,911	Hocking River (b)	8.5	302
Lima	53,734	Ottawa River (c)	2.0	70
Newark	41,836	Licking River	10.9	387
Norwalk	13,386	Huron River (d)	8.0	284
Tiffin	21,596	Sandusky River (e)	11.4	404
Upper Sandusky	5,645	Sandusky River	4.5	158
Wapakoneta	7,324	Auglaize River (f)	-	-
Washington Court House	12,495	Paint Creek (g)	2.4	84
Wooster	18,703	Killbuck Creek (h)	8.7	309

(a) Ungaged tributary to the Auglaize River

(b) Gage at Enterprise, Ohio, 17 km downstream of Lancaster

(c) Gage at Allentown, Ohio, 14 km downstream of Lima

(d) Gage at Milan, Ohio, 23 km downstream of Norwalk

(e) Gage at Mexico, Ohio, 13 km upstream of Tiffin

(f) Ungaged reach of river

(g) Gage at Greenfield, Ohio, 33 km downstream of Washington Court House

(h) Gage at Killbuck, Ohio, 40 km downstream of Wooster

PRELIMINARY SAMPLING LOCATION SELECTION

State, county and township maps and United States Geological Survey quadrangle maps were examined to select preliminary sampling locations for the dissolved oxygen measurements in the receiving waters upstream and downstream of the probable combined sewer outfalls in each of the thirteen towns. An attempt was made to estimate the dissolved oxygen deficits for each stream using the Streeter-Phelps equation: but the lack of published information concerning the sizes and the numbers of the combined sewers and the areas drained by them; the excess precipitation necessary to cause the combined sewers to overflow; and the geometric and hydraulic characteristics of the receiving streams made this a virtually impossible task. Instead, published reports of the impacts of combined sewer discharges from several of the towns under consideration were reviewed; and, based upon data included in these reports, a distance of 15 kilometers (0.9 miles) downstream of each town was selected as the probable region of impact.

When at all possible, the preliminary sampling sites were established at bridge crossings over the streams to be monitored. This resulted in clearly identifiable locations that were easily accessible to the crews that would make the field measurements. It permitted the dissolved oxygen measurements to be made near the middle of the stream where the values of the measurements were more representative of the general water quality, and it helped ensure that all measurements at a site would be made at comparable locations. Adequate off-the-road parking areas are generally available near bridge crossings, and highway traffic tends to be more cautious near bridges, so that the safety of the field crews was not jeopardized by the selection of these sites.

If the distance between bridge crossings downstream of a particular town were too widely spaced, intermediate sampling locations were selected. These sites were carefully chosen so that they were also easily accessible, clearly identifiable and safe. No criteria were established for a maximum distance between sampling sites at any town; but, in general, this spacing averaged around 3.6 kilometers (2.2 miles) measured along the stream.

DEVELOPMENT OF FIELD CREWS

Four field research teams, which consisted of one or two students from universities and colleges in the vicinity of the thirteen towns included in this study, were established. These teams included personnel from 1) the River Laboratory of Heidelberg College in Tiffin, Ohio under the supervision of Dr. David Baker, 2) the Lima Campus of the Ohio State University under the supervision of Dr. Kenneth R. Smith, 3) the Agricultural Technical College of the Ohio State University at Wooster, Ohio under the supervision of Professor Tommy L. Zimmerman, and 4) the Water Resources Center of the Ohio State University under the supervision of the principal investigator.

From geographical consideration, the researchers from Heidelberg College were assigned to make the measurements for the towns of Bucyrus, Upper Sandusky and Tiffin; while those researchers from Lima made the field

measurements for the towns of Lima, Delphos, Wapakoneta and Findlay, and those from the Agricultural Technical Institute made the measurements at Wooster. All the other field measurements and the task of collecting data and information about the combined sewer systems in the several towns were conducted by personnel from the Water Resources Center.

PRELIMINARY SITE VISITS

The superintendents of the municipal wastewater treatment facilities in each town were contacted to discuss the objectives of this study and to seek their cooperation in planning and conducting the field studies. Arrangements were made to visit each town to review with the superintendents any data on dissolved oxygen levels that they had for the streams flowing through their towns; and to discuss with them the preliminary sites that were selected for the sampling locations. During these visits the locations of the combined sewer outfalls in each town were ascertained and other information about the combined sewer system was solicited.

The field research teams assigned to each town accompanied the principal investigator and his staff on these site visits. With the assistance of the superintendents, the final sampling locations for the field measurements at each town were selected. The field crews and the principal investigator and his staff then visited each sampling location and planned the best travel route between them.

The field crews were instructed in the procedures to be used to make the field measurements and were shown where the measurements were to be made. The care and use of the dissolved oxygen monitoring equipment were described and the procedures to calibrate the equipment were reviewed.

Arrangements were also completed during these preliminary site visits to have the plant superintendents contact the field crews or their supervisors in the event that rain was forecast or imminent at a particular town. Originally it was thought that this type of alerting system could be established with the help of the United States Weather Service; but as the study plan developed, it appeared more convenient and appropriate to set up a more localized and personal system. In fact, since the field researchers were from the immediate vicinity of the towns they were to monitor, it frequently happened that no communication links were needed to inform them of impending rainfalls for a given town.

FINAL SITE SELECTION

During the preliminary site visits, the operators of the sewer systems in Lima, Ohio, indicated that a contract had been let to de-water the Ottawa River that flows through the town. This was done to permit the construction of a below-river storage system to collect the initial combined sewer discharges from the town during wet weather flows and hold them for later treatment at the municipal wastewater treatment plant. Since this would remove the combined sewer discharges to the Ottawa River, Lima was dropped from the

list of towns under consideration as sites for the more extensive field studies proposed. However, some field data were collected during this study to provide information on pre-construction conditions in the Ottawa River.

During the early phases of this study, an explosion in the combined sewer system in Akron, Ohio, caused extensive damage and permitted the direct and continuous discharge of untreated sewage to the Cuyahoga River. This would have eliminated Akron from consideration during this study; but town officials have been monitoring several of the combined sewer discharges for many years and they agreed to provide the principal investigator with these data to complete some aspects of this study.

A study of the topographic maps for Norwalk, Ohio, suggested that the stream patterns in that town were not suitable for the more extensive field program being proposed. There are several very small streams in and around the town that collect the combined sewage discharges. Each of these streams discharge in turn to different larger streams within a short distance from the outfalls. As a result, the field sampling program was not initiated in Norwalk, and the town of Washington Court House was added to the field studies.

Because of these changes, the list of twelve towns initially considered for this study was modified by the addition of Washington Court House and the deletion of Norwalk and Lima.

FIELD STUDIES

As noted earlier, the final locations for the field sampling programs for each town were established during the initial site visits. These locations were defined along the length of the stream by comparing them to the location of the municipal wastewater treatment plant which was assigned a zero kilometer reference value. The distances along the length of the stream were determined by scaling them from the maps used during the selection of the preliminary sampling locations. Sampling locations upstream of the plant were assigned negative kilometer values, while those downstream were assigned positive values. When dissolved oxygen measurements were made at sampling locations on tributaries to the principal stream on which the treatment plant was situated, the location of the mouth of the tributary was first referenced with respect to the wastewater treatment plant, and the sampling locations on the tributary were then referenced with respect to the confluence of the tributary and the principal stream. The convention of using upstream kilometer measurements as negative values was maintained.

The field crews were instructed to obtain background information on the dissolved oxygen values in the receiving waters at each sampling location in a town just prior to the start of a rainfall which subsequently caused the combined sewers to overflow. They were then to make dissolved oxygen measurements at successive sampling locations along the stream while the combined sewer outfalls were overflowing and to continue until the streams returned to their near normal dry weather flows. In several instances, however, it became necessary to determine the background information at other

times during the dry weather cycle and to concentrate the field efforts on obtaining dissolved oxygen measurements during and immediately following the rainfall occurrence.

Because much of the field sampling program was accomplished during the summer, the type of storm that most frequently caused the combined sewers to overflow was the convective thunderstorm so prevalent in the midwestern portion of the country during this time of the year. These storms often develop very quickly and are frequently very local in nature. They may only cause excess precipitation on a portion of a town, but they may also be part of a larger weather system that affects several neighboring communities at the same time.

Most of the municipal wastewater treatment plants operate their own rain gaging stations; and, where possible, arrangements were made to gather precipitation data from these sources for the day when dissolved oxygen levels in the streams were being monitored. However because of the nature of the storm systems that occurred during the field sampling period, the rainfall data collected at these gages was not always indicative of the rainfall in the central portion of the town that caused the combined sewers to discharge. In addition, since none of the municipal precipitation stations had recording rain gages, the timing of the rainfall at the gages in relation to the timing of the combined sewer overflows could not be determined from these station records.

Since one of the major objectives of this study was to determine if the combined sewer discharges from a town exerted a measureable impact on the dissolved oxygen in the receiving streams, the field crews were only instructed to note that the sewers were overflowing when they took their field measurements. The relationships between rainfall intensities and durations, and the degree of impact that the resulting combined sewer overflows have on the quality of the receiving streams will have to be investigated in the more extensive field studies that are proposed.

During the preliminary visits to the sampling sites the field crews had been instructed in the procedures they were to use to carry out the field measurements and had been shown where the measurements were to be made in the streams. The dissolved oxygen measurements were made in the field with a portable dissolved oxygen analyzer which utilizes a polarographic cell contained in a submersible probe as a sensing device. The instrument was a YSI Model 54 ARC dissolved oxygen meter and the polarographic cell was of the Clark type in which a silver anode and a concentric gold ring cathode are immersed in a potassium chloride electrolyte to form the cell. A replaceable plastic membrane, one mil thick, sealed the cell and confined the electrolyte.

The probe was equipped with an internal themistor which actuated circuits in the instrument to compensate for temperature effects and provided accurate dissolved oxygen readings at water temperatures other than those at which the device had been calibrated. Standardization of the probe and the operation and maintenance of the instrument were accomplished in accordance with the manufacturer's recommendations. The probe was attached to the battery-operated meter on the instrument by a 7.6 meter (20 foot) long transmitting

cable. The two measuring scales on the meter were graduated from 0 to 10 mg/l and 0 to 20 mg/l in intervals of 0.2 and 0.04 mg/l, respectively; and the accuracy of the measuring system was within one percent of the value measured.

When a field measurement was to be made, the pre-calibrated probe was lowered to the water by the cable until the face of the probe was submerged several centimeters. The actual depth was controlled so that the added turbulence caused by the probe in the stream did not cause air bubbles to be entrained near the probe and alter the water's existing dissolved oxygen value. In shallow streams, care was taken to ensure that the face of the probe was not damaged by coming into contact with the stream bed. The output reading was not recorded until the value indicated on the meter came to a stable endpoint. The water temperature was then read, and the value of the dissolved oxygen was re-measured. All measurements were made as near the stream surface as practical and as close to the center of the main body of flow in the stream as possible.

Any unique characteristics of the condition of the stream at the time of the measurement were noted and recorded. The field crews were trained to visually distinguish between wet and dry weather flow conditions in the stream at the time of measurement and to report these conditions with the other data.

OTHER INFORMATION

A staff member from the Water Resources Center participated in at least one series of measurements at each site with the researchers from the other units to make an assessment of the accessibility of each sampling site, and to note any problems associated with the field procedures.

Other bits of information including the location of stream gages, stream gaging records, reports on the combined sewer system in the several towns, etc., were also collected at the Water Resources Center.

SECTION 4

RESULTS AND DISCUSSION

The results of this study are presented in the form of a fact sheet for each community investigated along with graphs of the dissolved oxygen measurements obtained during the field sampling program. A brief analysis of the information and data that were collected at each site is also provided and a recommendation as to the desireability of selecting the community for further study is made.

Each fact sheet includes the name, location and population of the town studied. It also contains a diagram which shows the stream patterns in the vicinity of the town. The locations of the municipal sewage treatment plant (STP), the field sampling sites and the stream gaging stations on the receiving stream are shown on the diagram.

The fact sheet further defines the locations of the field sampling sites and of the combined sewer overflows along the receiving stream by identifying their locations along the river relative to the municipal sewage treatment plant in kilometers (km) and miles. The field sampling sites are also described according to the name or number of the road, bridge crossing or community at those sites.

An assessment of the accessibility of the field sampling sites is provided along with references to other published reports on the combined sewer system and the name, address and telephone number of the superintendent of the municipal sewage treatment plant.

The values of the dissolved oxygen concentrations from the field sampling program are compared graphically with the distances along the receiving streams. Several sets of results are presented for each town investigated; and information about the dates, times, stream conditions and rainfall that existed when the field tests were being conducted are presented.

For the purpose of demonstrating that the combined sewer overflows did impact the receiving streams in this study, some minimum acceptable level of dissolved oxygen in the stream had to be established. The Ohio Environmental Protection Agency has adopted water quality standards that require that the dissolved oxygen levels in all streams in the state be maintained at 5.0 mg/l for at least 16 hours per day and that the values never be less than 4.0 mg/l. The standards also require that a dissolved oxygen concentration of 6.0 mg/l be maintained at all times in streams designated as cold water fisheries. None of the streams considered in

this study have been classified as cold water fisheries. The dissolved oxygen criteria proposed by the United States Environmental Protection Agency suggest that a minimum concentration of 5.0 mg/l is needed to maintain good fish populations. Since these two principal agencies include a reference to a minimum value of 5.0 mg/l for the dissolved oxygen level to be maintained in streams, this value has also been adopted for this study and is included on the graphical results shown for each town studied.

The summaries of the field determinations that were conducted during this study are presented in the fact sheets and include among other items the values of the precipitation and stream flows for those sites where the information could be obtained. The precipitation data were either collected from the superintendents of the municipal sewage treatment plants or were taken from the published records of the National Weather Service. The data on daily stream flows were taken from the Water Data Reports (OH-77-1 and OH-77-2) of the United States Geological Survey. Care must be exercised in interpreting and comparing the precipitation and the stream flow data however, for they are either total or mean daily values and they generally cover different time periods. The information on precipitation is reported for the 24 hour period before 7:00 AM on the reporting day and represents the total rainfall collected during that time period. The stream flow data are the mean daily flows for the day of record if the measuring gage is a continuous monitoring device and are the instantaneous flows if a staff gage was used. These data represent important values to be considered in the evaluation of the results of this study, but more comprehensive data on these two items must be collected and interpreted in the in-depth studies on the impacts of urban runoff that have been proposed.

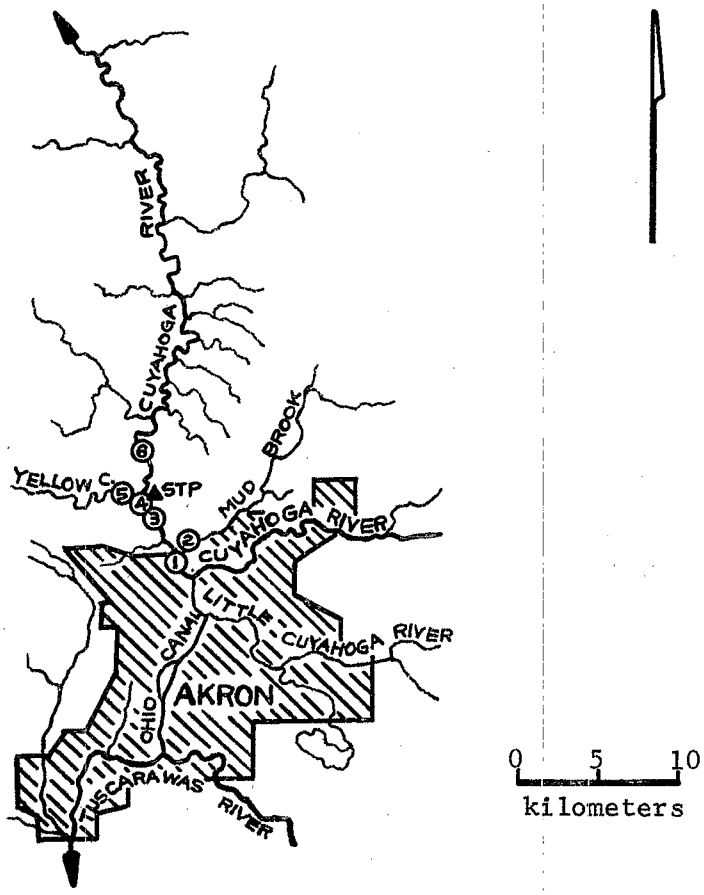
The results for each town considered in this study also include a brief analysis of the information presented in the fact sheet and of the data included in the graphical presentations. Finally, a recommendation concerning the desirability of conducting further studies on the impact that the combined sewer discharges have on the receiving stream at the town is presented.

Name AKRON

Location Summit County, Ohio

Population (year) 261,520 (1973)

Site Map



Sampling Sites

No.	Stream	River Location kms	River Location miles	Description
1	Cuyahoga R.	-4.7	-2.9	Gaging Station @ Portage Path
2	Mud Brook	-4.2	-2.6	Mud Brook @ Cuyahoga R.
3	Cuyahoga R.	-1.3	-0.8	Akron Peninsula Rd. @ Hardy Rd.
Ref	Cuyahoga R.	0.0	0.0	STP
4	Cuyahoga R.	0.2	0.1	Barth Rd. Br.
5	Yellow Creek	0.3	0.2	Yellow C. @ Cuyahoga R.
6	Cuyahoga R.	2.7	1.7	Martin Rd. @ Oak Hill Rd. Br.

Receiving Streams

In town	Cuyahoga River Little Cuyahoga River (Trib. to Cuyahoga River) Springfield Lake Outlet (Trib. to L. Cuyahoga R.) Ohio Canal (connected to L. Cuyahoga R.) Sand Run (Trib. to Cuyahoga River)
Downstream	Cuyahoga River Mud Brook (Trib. to Cuyahoga River) Sand Run (Trib. to Cuyahoga River) Yellow Creek (Trib. to Cuyahoga River) Furnace Creek (Trib. to Cuyahoga River)

Combined Sewer Outfalls

Stream	No.	River Location
Ohio Canal	15	In town
Sand Run	11	"
L. Cuyahoga R.	36	"
Cuyahoga R.	2	"

Stream Gages

Stream	Gage No.	Location	Type	Operation
Cuyahoga R.	04206000	Portage Path	Flow/Quality	USGS

Accessibility of Sampling Sites

The sampling sites were selected by the city for its weekly sampling program to monitor water quality above and below the sewage treatment plant.

Other Available Information

The city provides annual reports on the condition and operation of the combined sewers outfalls.

Sewage Treatment Plant

Superintendent:	James White
Address:	2460 Peninsula Road Akron, Ohio 44313
Phone:	216-928-1164

Summary of Field Determinations

The city monitors water quality at six locations along streams throughout the system on a weekly basis. Because of an explosion in the combined storm system in Akron and the continuous release of sanitary sewage to the Cuyahoga River during the early portions of these studies, the data used for this study were taken from these weekly sampling efforts. They reflect different conditions in the stream flows and in the operation of the combined sewer discharges. These tests are normally made around 9:00 AM.

Figure Number	Date	Field Conditions
1-A	5/16/77	Dry weather stream flow (5.1 m^3/s); no combined sewer discharges.
1-B	5/31/77	Wet weather stream flow (4.5 m^3/s) following light rainfall (0.20 cm); combined sewer discharges.
1-C	6/29/77	Wet weather stream flow (11.6 m^3/s) during moderate rainfall (0.56 cm); combined sewer discharges.

Analysis of Results

Figure 1-A May 16, 1977 9:00 AM
Dry weather stream flow (5.1 m^3/s); no combined sewer discharges.

Figure 1-B May 31, 1977 9:00 AM
Wet weather stream flow (4.50 m^3/s) following light rainfall (0.20 cm); combined sewer discharges.

Figure 1-C June 29, 1977 9:00 AM
Wet weather stream flow (11.6 m^3/s) during moderate rainfall (0.56 cm); combined sewer discharges.

Figure 1-A shows that the level of the dissolved oxygen in the Cuyahoga River and some of its tributaries during typical dry weather flow periods is of acceptable values. Following combined sewer discharges during wet weather flows, however, the values of the dissolved oxygen in the stream above the sewage treatment plant are reduced (Figures 1-B and 1-C). The added flow from the plant and Yellow Creek tends to restore the dissolved oxygen to more acceptable levels.

Recommendations

The drainage patterns in Akron and the complexities of the city's vast combined sewer system are adequate reasons not to recommend this site as a location for more extensive studies on the impact of combined sewer discharges on receiving streams.

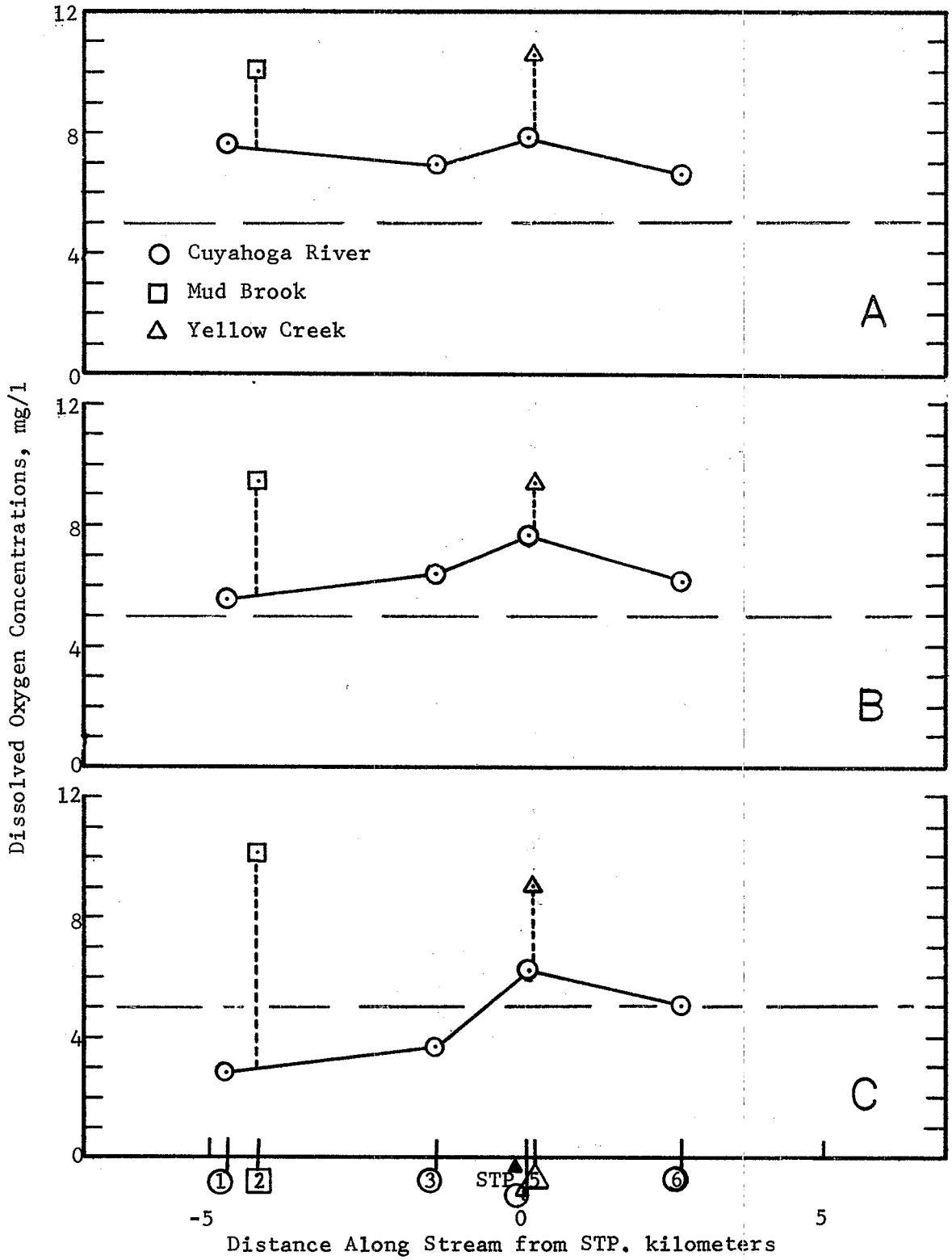
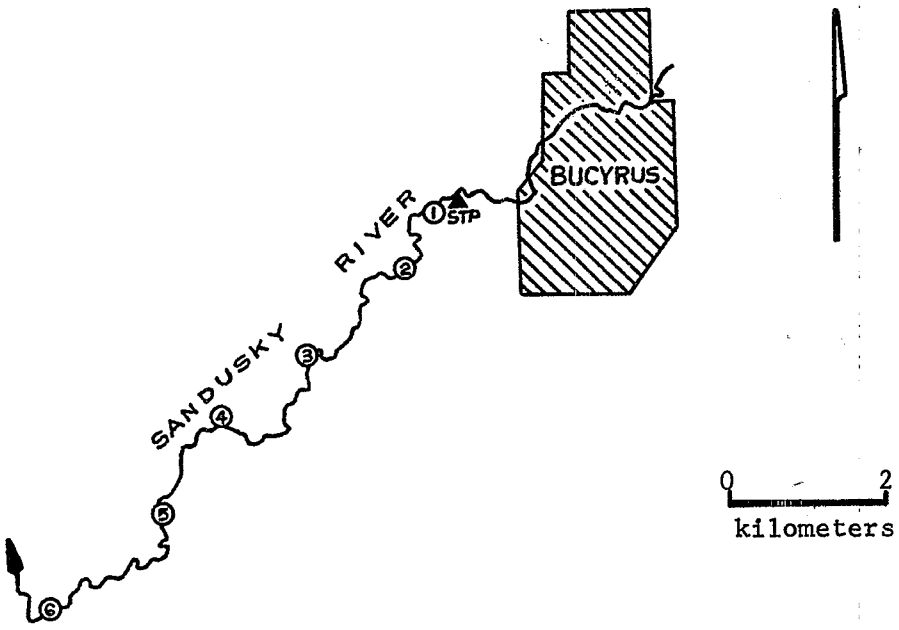


Figure 1. Dissolved oxygen profiles - Akron.

Name BUCYRUS
Location Crawford County, Ohio

Population (year) 13,076 (1973)

Site Map



Receiving Stream

In town	Sandusky River
Downstream	Sandusky River

Sampling Sites

No.	Stream	River Location kms	River Location miles	Description
Ref	Sandusky R.	0.0	0.0	STP
1	"	0.8	0.5	Kestetter Rd. Br.
2	"	4.3	2.7	Denzer R. Br.
3	"	7.7	4.8	Mt. Zion
4	"	11.2	7.0	Knauss
5	"	14.4	9.0	Caldwell Rd. Br.
6	"	17.4	10.9	County Line Rd. Br.

Combined Sewer Outfalls

Stream	No.	River Location
Sandusky R.	24	In town

Stream Gages

Stream	Gage No.	Location	Type	Operation
Sandusky R.	04196000	Kestetter Rd.	Flow/Quality	USGS

Accessibility of Sampling Sites

The accessibility of the sampling sites is excellent. There is only one stream to sample; all of the sites are located downstream of the town and are at highway bridge crossings; and there are good, all-weather roads between the sampling locations.

Other Available Information

Report on Combined Sewer Overflows by Burgess and Niple, Ltd., Columbus, Ohio, November 1969.

Sewage Treatment Plant

Superintendent:	Jerry Staiger
Address:	W. Southern Avenue Bucyrus, Ohio 44820
Phone:	419-562-8981

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
2-A	6/29/77 6:45 - 7:30 AM	Dry weather stream flow prior to anticipated rainfall; no combined sewer discharges.
2-B	6/29/77 1:25 - 2:30 PM	Wet weather stream flow (0.22 m^3/s) during light rainfall (0.96 cm); combined sewer discharges.
2-C	6/30/77 9:00 - 9:50 AM	Dry weather stream flow (0.91 m^3/s) following rainfall on previous day; no combined sewer discharges.

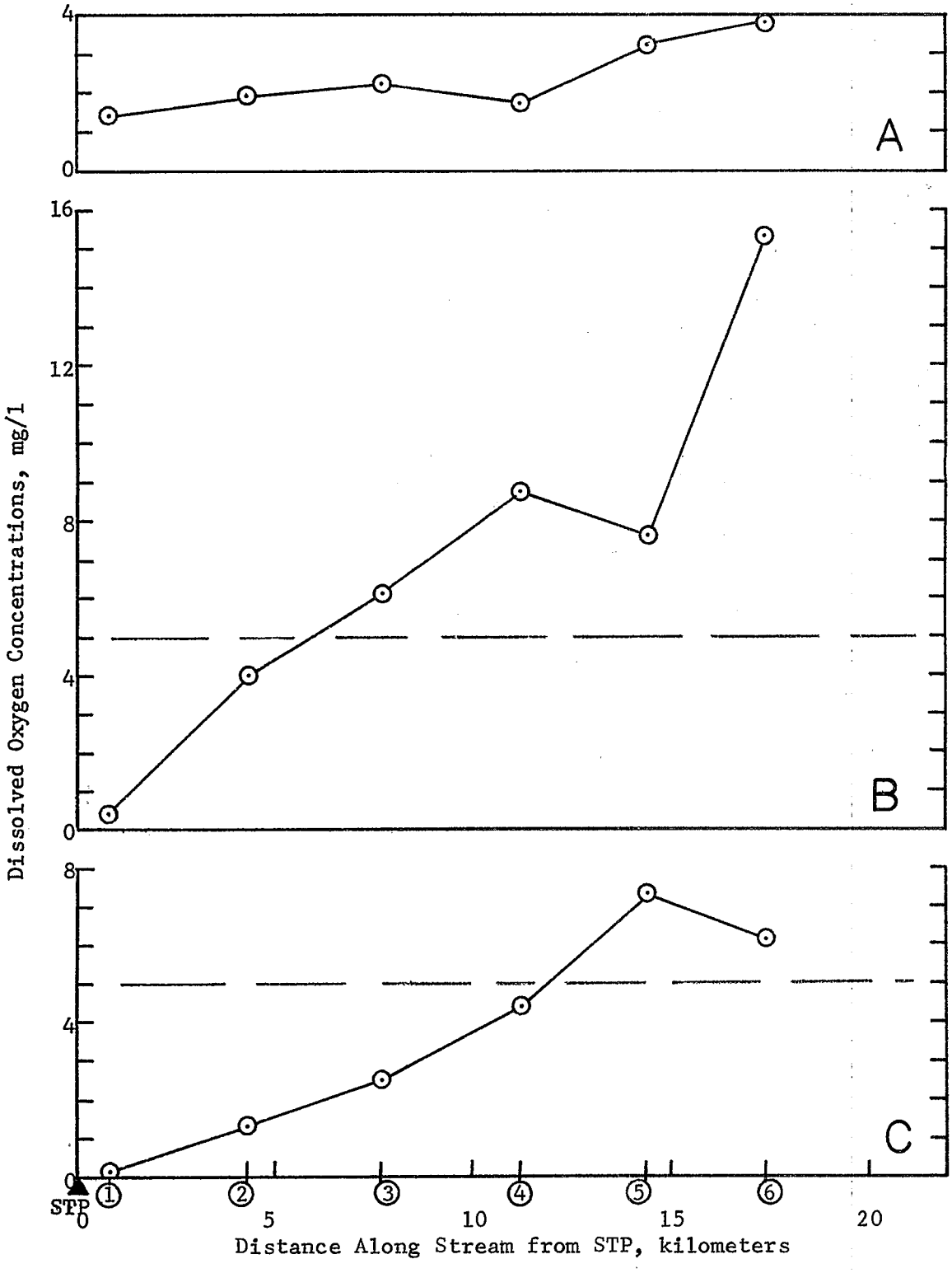


Figure 2. Dissolved oxygen profiles - Bucyrus.

Analysis of Results

Figure 2-A June 29, 1977 6:45 to 7:30 AM
Dry weather stream flow prior to anticipated rainfall; no combined sewer discharges.

Figure 2-B June 29, 1977 1:25 to 2:30 PM
Wet weather stream flow (0.22 m^3/s) during light rainfall (0.96 cm); combined sewer discharges.

Figure 2-C June 30, 1977 9:00 to 9:50 AM
Dry weather stream flow (0.91 m^3/s) following rainfall on preceeding day; no combined sewer discharges.

The results are indicative of the impact that the poor quality effluent from the Bucyrus sewage treatment plant has on the dissolved oxygen concentrations in the Sandusky River. During dry weather flows (Figure 2-A), the dissolved oxygen levels remain below 4 mg/l for nearly 20 kilometers downstream of town. Following a rainfall sufficient to cause the combined sewers to overflow, the stream's dissolved oxygen levels show a marked increase (Figure 2-B), apparently due to the addition of surface runoff to the stream flow. However, the dissolved oxygen levels near the treatment plant are still quite low. Figure 2-C shows the stream's dissolved oxygen levels returning to the lower values that are typical for dry weather flows.

Recommendations

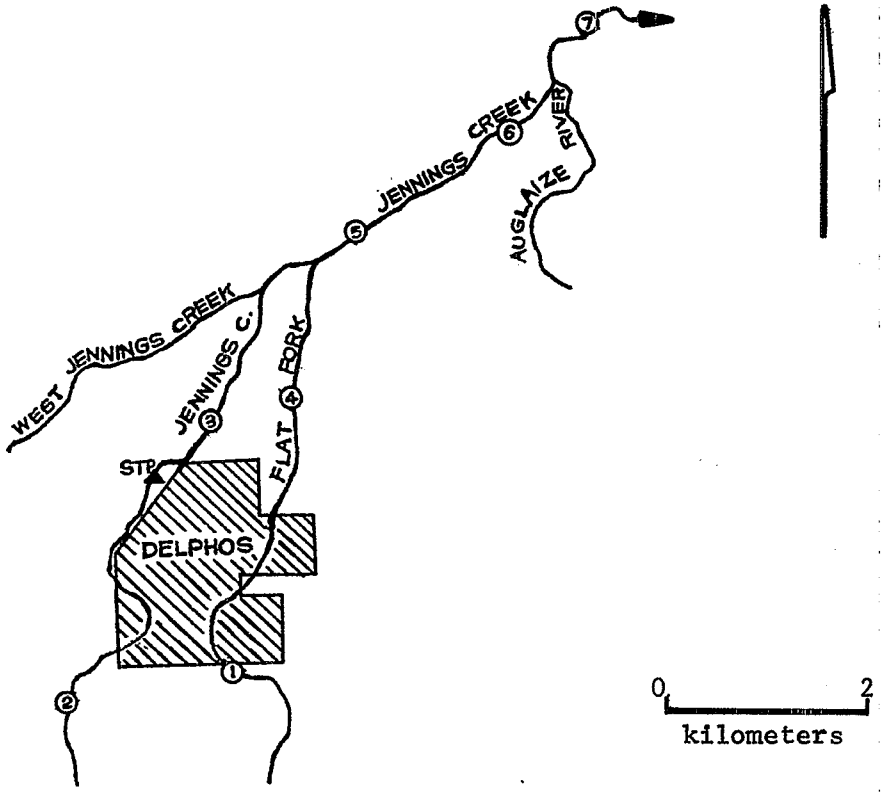
The very marked effect that the effluent from the Bucyrus sewage treatment plant has on dissolved oxygen levels in the Sandusky River masks the detection of the impacts that combined sewage discharges have on the receiving stream, and further studies at Bucyrus are not recommended.

Name DELPHOS

Location Allen County, Ohio

Population (year) 7,718 (1973)

Site Map



Sampling Sites

No.	Stream	River Location kms	River Location miles	Description
1	Flat Fork	-6.7	-4.2	S.R. 66 Br.
2	Jennings C.	-4.8	-3.0	T.R. 244 Br.
Ref	"	0.0	0.0	STP
3	"	0.5	0.3	Pohlman Rd. Br.
4	Flat Fork	-2.7	-1.7	S.R. 66 Br.
5	Jennings C.	4.8	3.0	S.R. 190 Br.
6	"	7.2	4.5	T.R. 23 Br.
7	Auglaize R.	0.8	0.5	S.R. 189 Br.

Receiving Streams

In town	Flat Fork (Trib. to Jennings Creek @ +4.3 kms) Jennings Creek (Trib. to Auglaize River @ +8.0 kms)
Downstream	Flat Fork Jennings Creek Auglaize River

Combined Sewer Outfalls

Stream	No.	River Locations
Flat Fork	3	In town
Jennings Creek	5	In town

Stream Gages

None on Jennings Creek.

Accessibility of Sampling Sites

The accessibility of the sampling sites is fair to very good. Delphos is a relatively small town, but there are two streams to monitor and traffic congestion and railroad crossings often slow crosstown movement. The downstream sampling sites are at bridge crossings and travel conditions between them are very good.

Other Available Information

Report on Delphos Sewer System by Finkbeiner, Pettis and Strout, Ltd., Toledo, Ohio, 1976.

Sewage Treatment Plant

Superintendent:	Harold Hodges
Address:	1100 N. Park Avenue Delphos, Ohio 45833
Phone:	419-692-0991

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
3-A	6/25/77 11:10 AM - 12:40 PM	Dry weather stream flow following light rain (0.4 cm) on preceding day; no combined sewer discharges.
3-B	6/29/77 3:30 - 4:50 PM	Wet weather stream flow following two days of moderate rainfall (2.8 cm total); combined sewer discharges.
3-C	6/30/77 3:00 - 4:00 AM	Dry weather stream flow; no combined sewer discharges.

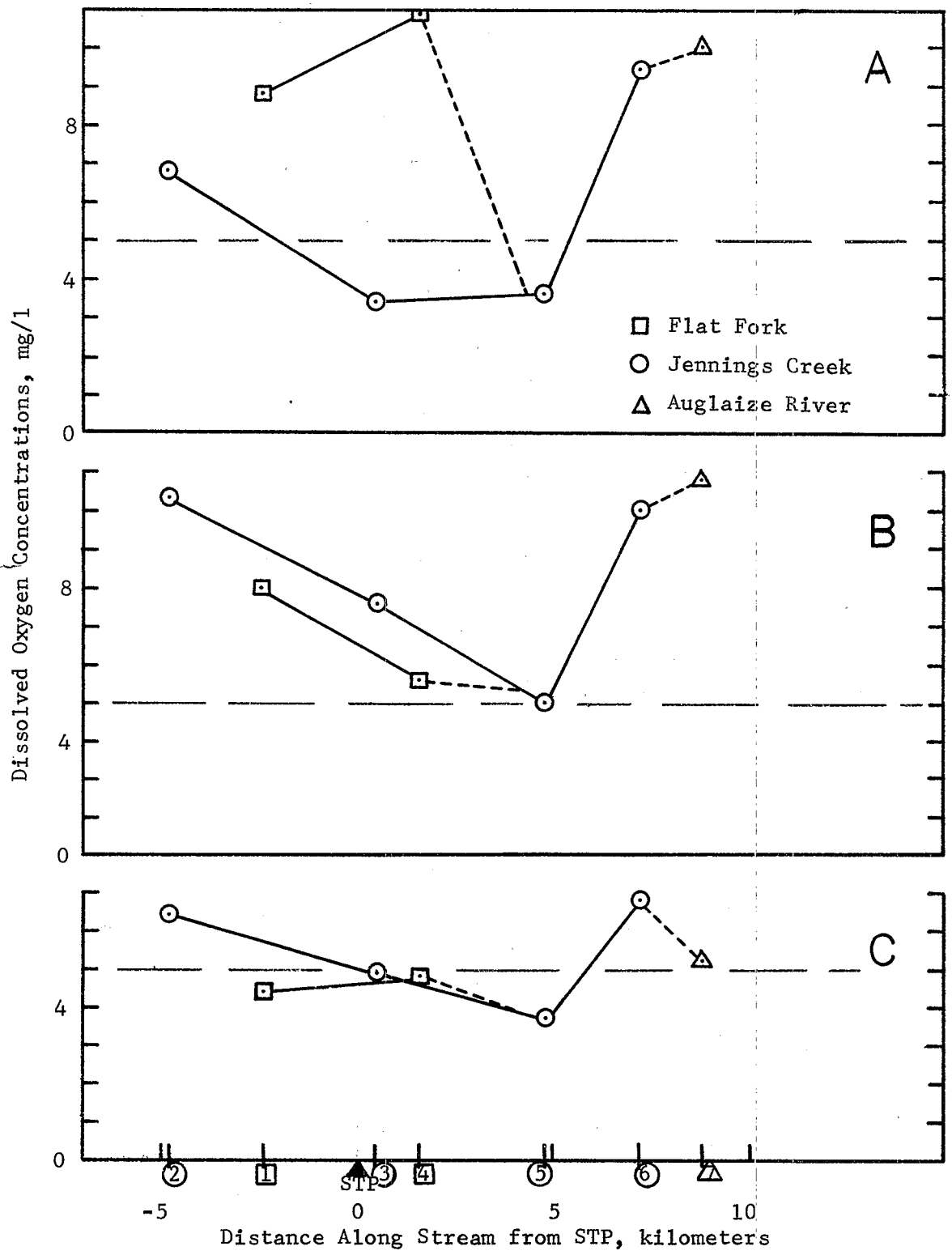


Figure 3. Dissolved oxygen profiles - Delphos.

Analysis of Results

Figure 3-A June 25, 1977 11:00 AM to 12:40 PM
Dry weather stream flow following light rain (0.4 cm) on preceding day; no combined sewer discharges.

Figure 3-B June 29, 1977 3:30 to 4:50 PM
Wet weather stream flow following two days of moderate rainfall (2.8 cm total); combined sewer discharges.

Figure 3-C June 30, 1977 3:00 to 4:00 AM
Dry weather stream flow; no combined sewer discharges.

The results show the impact that the effluent from the Delphos sewage treatment plant has on the dissolved oxygen levels in Jennings Creek. During dry weather flows (Figure 3-A), the values are less than 4 mg/l immediately downstream of town. However, they are at more acceptable levels in Flat Fork and in the nearby, but much larger, Auglaize River. During wet weather flows (Figure 3-B), the input of surface water has generally improved the levels of oxygen in Jennings Creek above and in town, whereas the addition of combined sewage from the outfalls to Flat Fork and Jennings Creek has lessened water quality further downstream. As the flow in the streams returns to normal, the material from the previous combined sewer discharges continues to exert an impact on the dissolved oxygen levels in both Flat Fork and Jennings Creek (Figure 3-C). The dissolved oxygen value in the Auglaize River is still at an acceptable level.

Recommendations

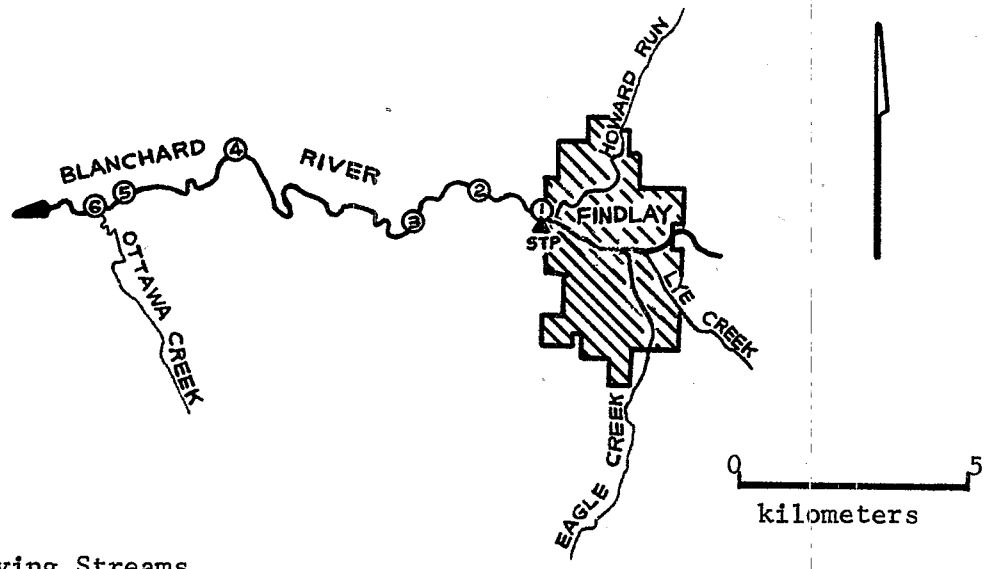
The discharge of combined sewage from Delphos does adversely impact the dissolved oxygen levels in Flat Fork and Jennings Creek, but does not seriously impair the Auglaize River. The relatively short lengths of the streams between the town and the Auglaize River, and the relatively poor quality of the effluent from the sewage treatment plant preclude any further studies at Delphos.

Name FINDLAY

Location Hancock County, Ohio

Population (year) 36,109 (1973)

Site Map



Receiving Streams

In town	Lye Creek (Trib. to Blanchard R. @ -1.6 kms) Eagle Creek (Trib. to Blanchard R. @ -1.3 kms) Howard Run (Trib. to Blanchard R. @ -0.2 kms) Blanchard River
Downstream	Blanchard River

Sampling Sites

No.	Stream	River Location kms	River Location miles	Description
Ref	Blanchard R.	0.0	0.0	STP
1	"	0.2	0.1	Broad Ave. Br.
2	"	2.4	1.5	C.R. 140 Br.
3	"	4.8	3.0	C.R. 139 Br.
4	"	10.9	6.8	C.R. 128 Br.
5	"	16.1	10.0	S.R. 235 Br.
6	"	33.6	20.9	Gilboa

Combined Sewer Outfalls

Stream	No.	River Locations
Eagle C.	2	In town
Howard R.	1	In town
Blanchard R.	7	In town

Stream Gages

Stream	Gage No.	Location	Type	Operation
Blanchard R.	0418900	C.R. 140	Flow/Quality	USGS

Accessibility of Sampling Sites

The accessibility of the sampling sites is very good. There is only one stream to sample and most of the sites are downstream of the town at bridge crossings.

Other Available Information

Report on Combined Sewer Overflows by John R. Snell, Engineers, Inc., Lansing, Michigan.

Sewage Treatment Plant

Superintendent:	Jim Ball
Address:	Sewage Treatment Plant Findlay, Ohio 45840
Phone:	419-422-4912

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
4-A	5/27/77 11:30 AM - 2:30 PM	Dry weather stream flow (0.93 m^3/s); no combined sewer discharges.
4-B	6/30/77 2:00 - 2:50 PM	Wet weather stream flow (3.46 m^3/s) during heavy rainfall (6.4 cm); combined sewer discharges.

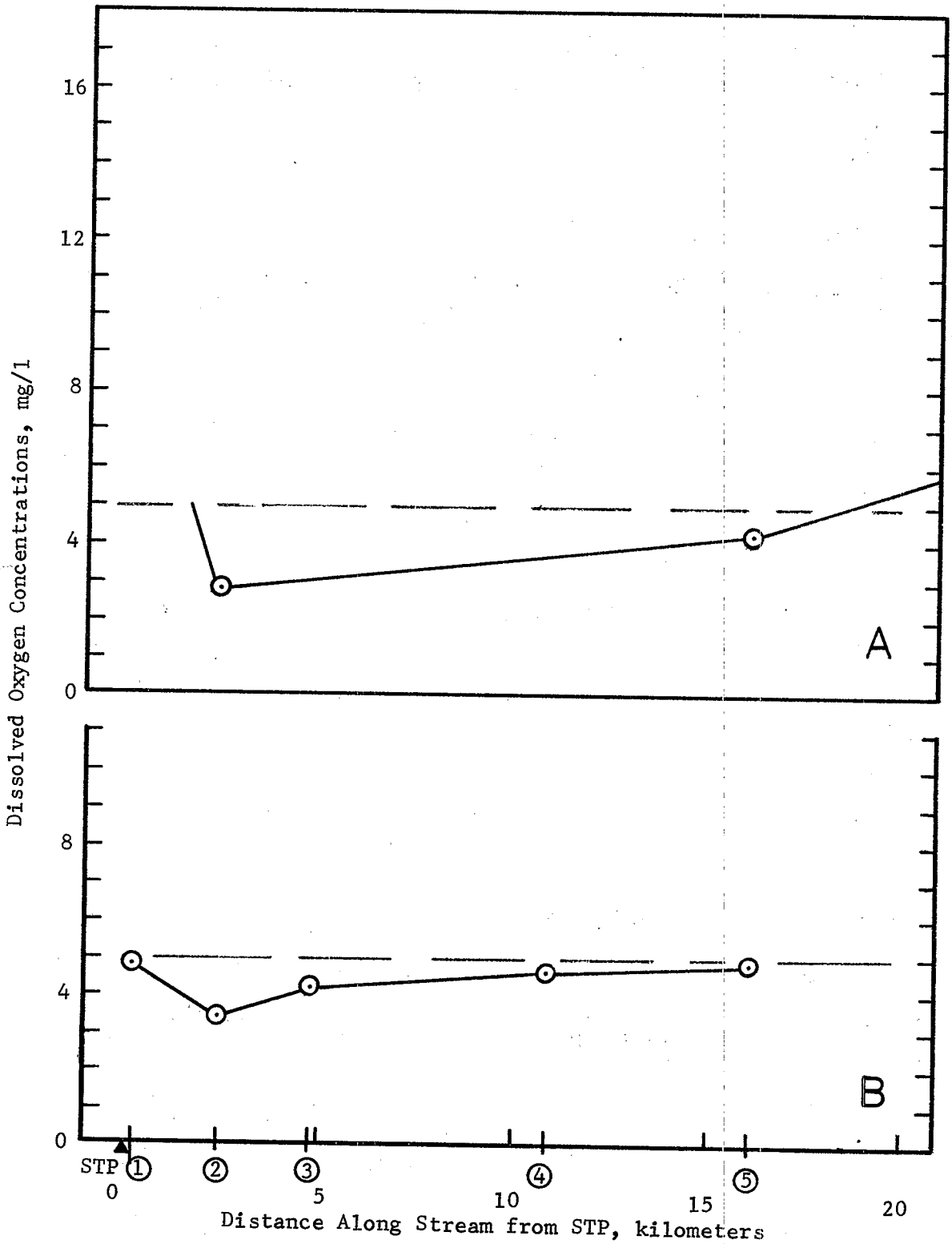


Figure 4. Dissolved oxygen profiles - Findlay.

Analysis of Results

Figure 4-A May 27, 1977 11:30 AM to 2:30 PM
Dry weather stream flow (0.93 m^3/s); no combined sewer discharges.

Figure 4-B June 30, 1977 2:00 to 2:50 PM
Wet weather stream flow (3.46 m^3/s) during heavy rainfall (6.4 cm); combined sewer discharges.

The results indicate the impact that the relatively poor quality effluent from the sewage treatment plant at Findlay has on the dissolved oxygen levels in the Blanchard River. During dry weather flow (Figure 4-A), the values of dissolved oxygen are less than 4 mg/1 for over 15 kilometers downstream of the town. During wet weather flows (Figure 4-B), the addition of surface runoff along with combined sewage has improved the dissolved oxygen levels below Findlay slightly, but the values are still below 5 mg/1.

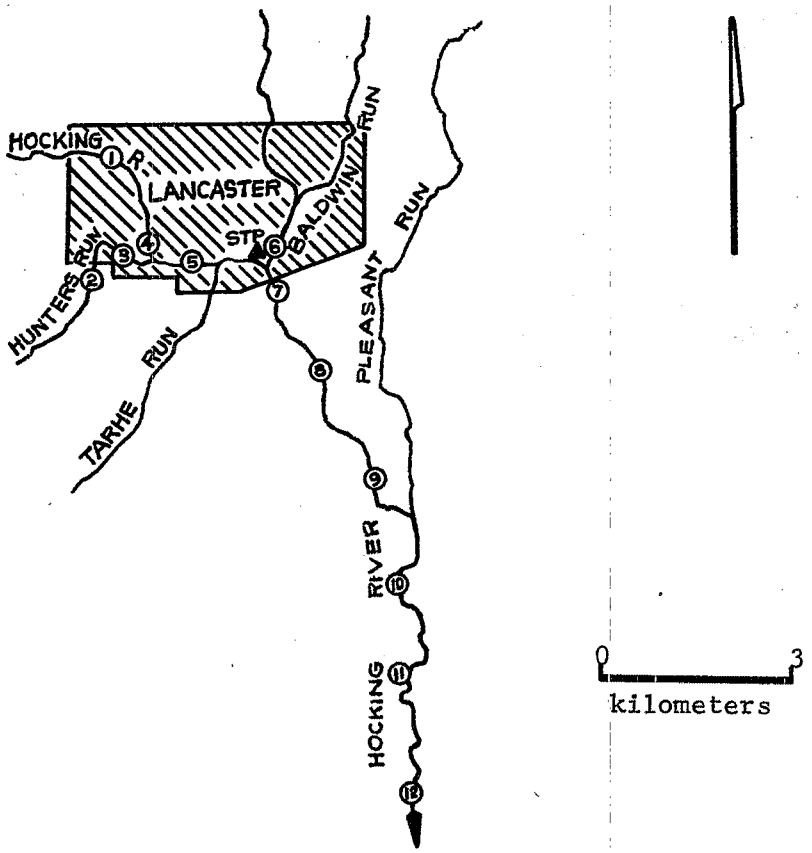
Recommendation

Further studies at Findlay are not recommended because of the impact that the effluent from the sewage treatment plant has on dissolved oxygen levels in the receiving stream.

Name LANCASTER
Location Fairfield County, Ohio

Population (year) 35,417 (1973)

Site Map



Sampling Sites

No.	Stream	River Location kms	River Location miles	Description
1	Hocking R.	-4.8	-3.0	Pierce Ave. Br.
2	Hunter's R.	-1.6	-1.0	U.S. Rt. 22 Br.
3	"	-0.6	-0.4	U.S. Rt. 22 Br.
4	Hocking R.	-2.4	-1.5	U.S. Rt. 22 Br.
5	"	-1.1	-0.7	Columbus St. Br.
6	Baldwin R.	-0.2	-0.1	Duffy Rd. Br.
Ref	Hocking R.	0.0	0.0	STP
7	"	1.0	0.6	Sugar Grove Rd. Br.
8	"	2.7	1.7	U.S. Rt. 33-gravel pit
9	"	5.4	3.4	U.S. Rt. 33 Br.
10	"	7.7	4.8	Horns Mill Rd. Br.
11	"	9.1	5.7	U.S. Rt. 33 Br.
12	"	10.7	6.7	Sugar Grove Br.

Receiving Streams

In town	Hocking River Hunter's Run (Trib. to Hocking R. @ -2.1 kms) Tarhe Run (Trib. to Hocking R. @ -0.8 kms) Baldwin Run (Trib. to Hocking R. @ 0.0 kms) Fetter's Run (Trib. to Baldwin R. @ -1.5 kms)
Downstream	Hocking River

Combined Sewer Outfalls

Stream	No.	River Locations
Hocking R.	24	-5.0 to 0.0 kms
Hunter's R.	1	In town
Tarhe R.	1	"
Baldwin R.	6	"
Fetter's R.	1	"

Stream Gages

Stream	Gage No.	Location	Type	Operation
Hunter's R.	03156000	Lane Rd.	Flow/Quality	USGS
Hocking R.	03156400	Columbus St.	Flow	Discontinued
Hocking R.	03157500	Enterprise,Oh.	Flow/Quality	USGS

Accessibility of Sampling Sites

The accessibility of the sampling sites is fair. Lancaster is a fairly large town with normal and rush hour traffic congestion. There are several streams to sample in town and cross town travel is complicated with many traffic lights. There is excellent access to the downstream sampling sites along one major highway which parallels the receiving stream.

Other Available Information

Report on Infiltration and Interception by Sico, Inc., Delaware, Ohio.

Sewage Treatment Plant

Superintendent:	Lloyd Hedges
Address:	800 S. Lawrence Street Lancaster, Ohio 43130
Phone:	614-653-1754

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
5-A	6/6/77 9:30 AM - 12:25 PM	Dry weather stream flow (3.12 m^3/s) prior to anticipated rainfall; no combined sewer discharges.
5-B & 5-C	6/8 - 9/77 11:15 PM - 12:45 AM (B) 3:15 - 3:30 AM (C)	Wet weather stream flow (2.80 m^3/s) following rain (1.5 cm); combined sewer discharges.
5-D	6/9/77 4:00 - 5:25 AM	Wet weather stream flow (3.96 m^3/s); combined sewer discharges.
5-E	6/28/77 2:50 - 4:20 PM	Wet weather stream flow (12.8 m^3/s) during rain (1.1 cm); combined sewer discharges.
5-F	6/28/77 4:54 - 6:00 PM	Wet weather stream flow during rainfall; combined sewer discharges.
5-G & 5-H	6/28/77 6:15 - 6:35 PM (G) 8:09 - 8:50 PM (H)	Wet weather stream flow during rainfall; combined sewer discharges.
5-I	7/26/77 3:30 - 5:10 PM	Wet weather stream flow (3.34 m^3/s) during rain (1.07 cm); combined sewer discharges.
5-J	7/26/77 6:55 - 8:15 PM	Wet weather stream flow; no combined sewer discharges.
5-K	7/26/77 8:25 - 8:50 PM	Wet weather stream flow; no combined sewer discharges.
5-L	7/26 - 27/77 11:10 PM - 12:25 AM	Wet weather stream flow; no combined sewer discharges.
5-M	7/27/77 8:35 - 9:55 AM	Dry weather stream flow (2.15 m^3/s); no combined sewer discharges.
5-N	7/27/77 12:30 AM - 1:45 PM	Dry weather stream flow; no combined sewer discharges.

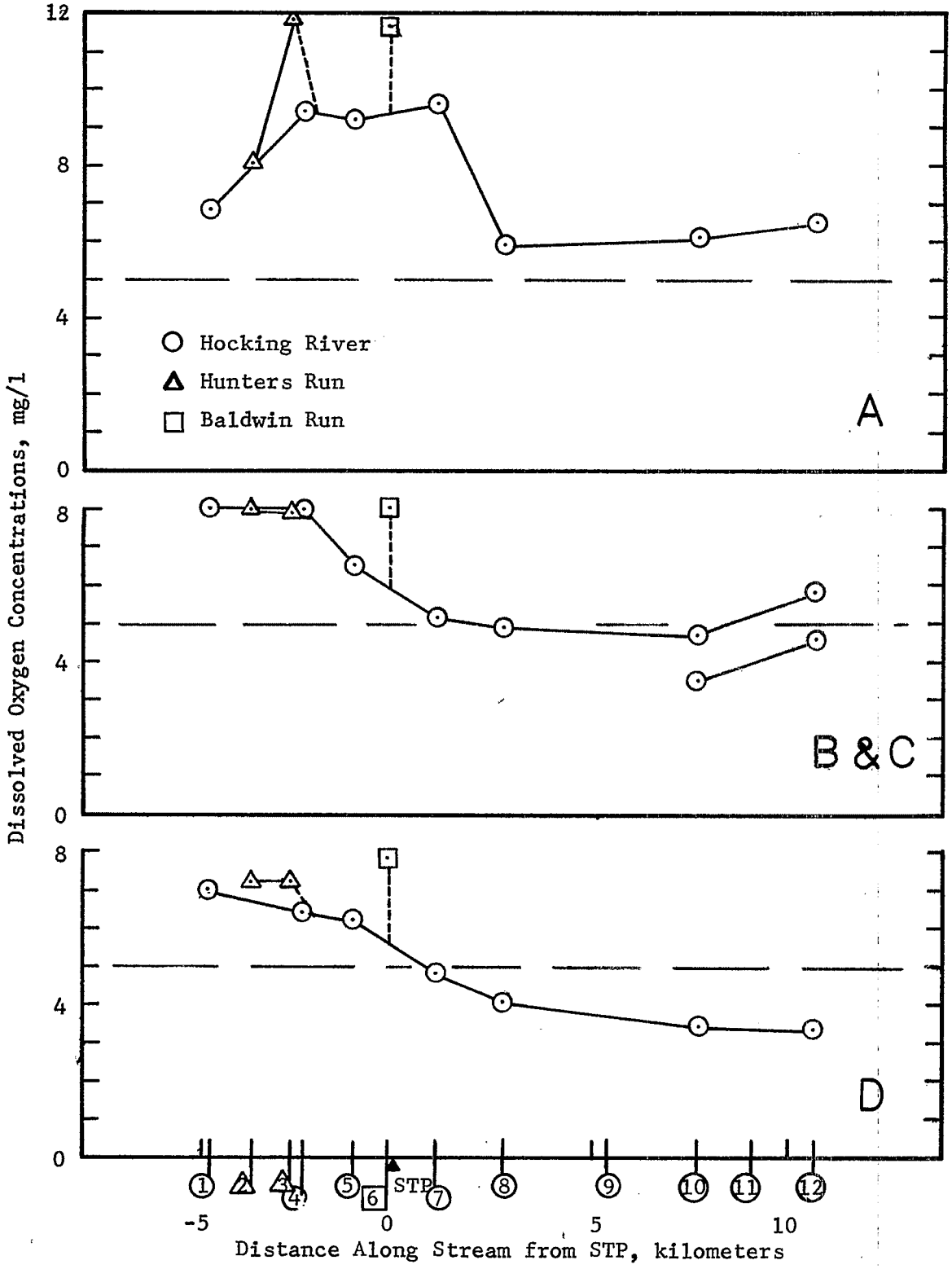


Figure 5. Dissolved oxygen profiles - Lancaster.

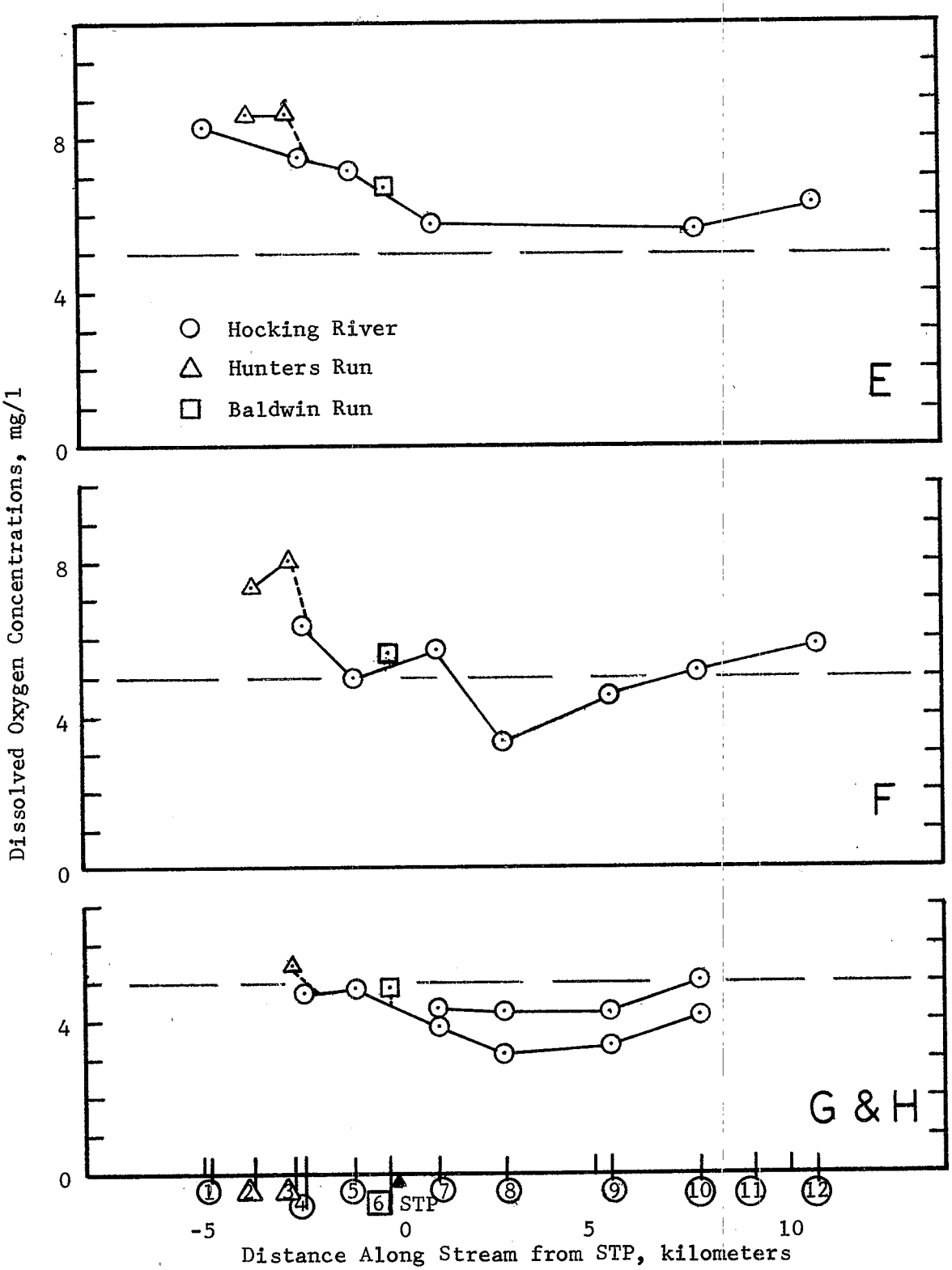


Figure 5. Dissolved oxygen profiles - Lancaster.

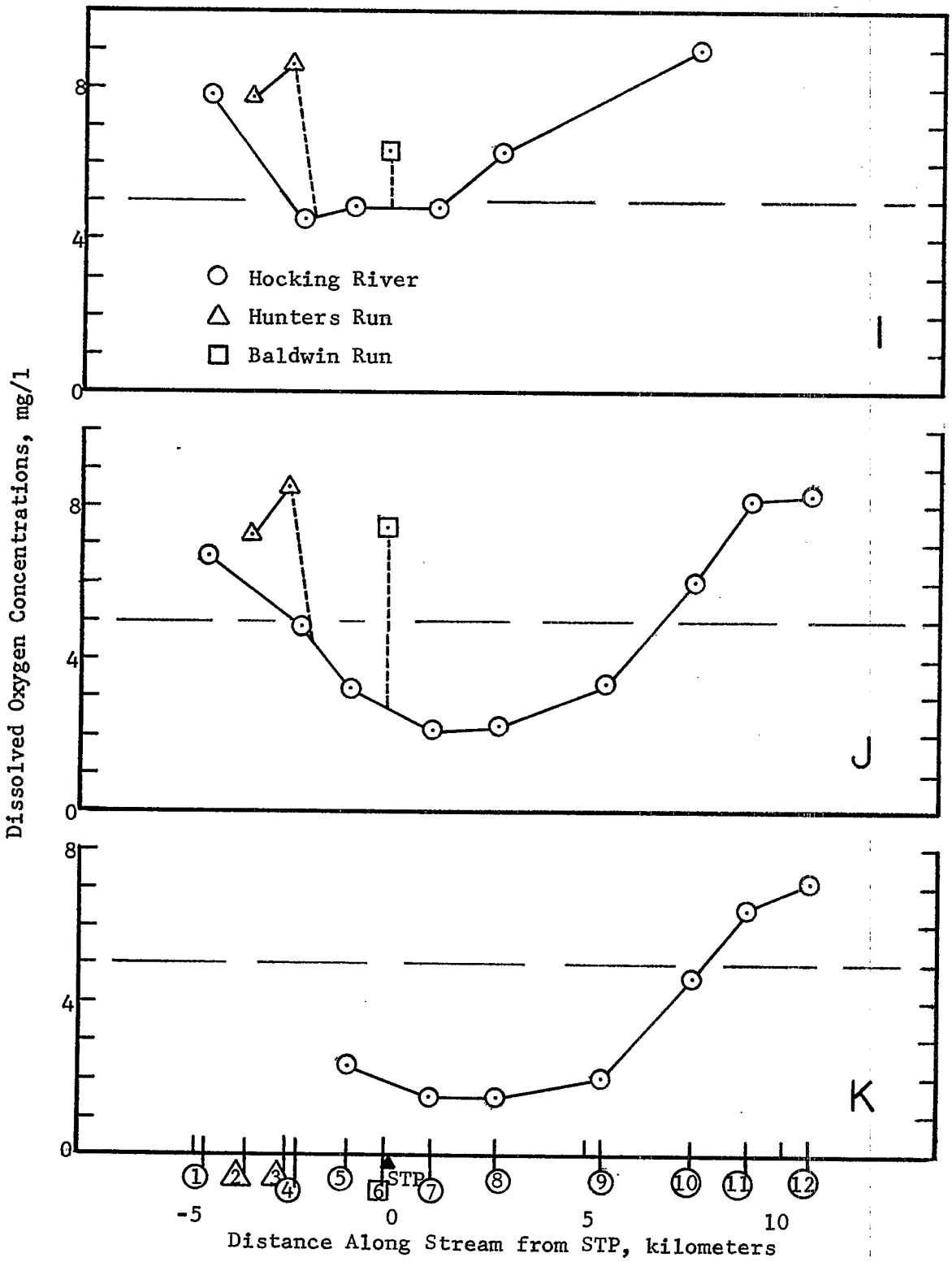


Figure 5. Dissolved oxygen profiles - Lancaster.

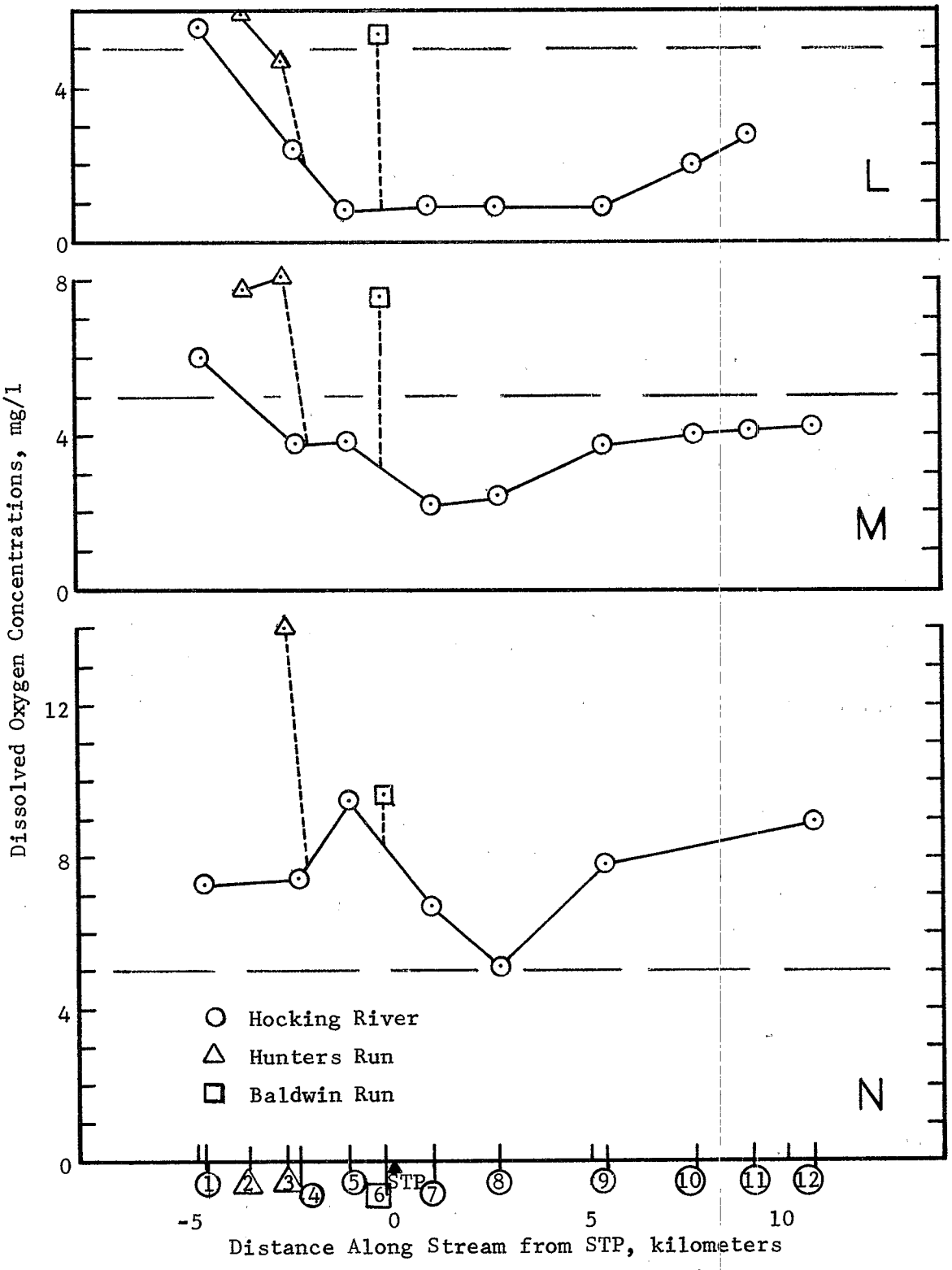


Figure 5. Dissolved oxygen profiles - Lancaster.

Analysis of Results

Figure 5-A June 6, 1977 9:30 AM to 12:25 PM
Dry weather stream flow (3.12 m^3/s) prior to anticipated rainfall; no combined sewer discharges.

Figure 5-B & 5-C June 8-9, 1977 11:15 PM to 3:30 AM
Wet weather stream flow (2.80 m^3/s) following rain (1.5 cm); combined sewer discharges.

Figure 5-D June 9, 1977 4:00 to 5:25 AM
Wet weather stream flow (3.96 m^3/s); combined sewer discharges.

This sequence of graphs shows the normal dissolved oxygen levels in the Hocking River during dry weather flows (Figure 5-A), and the development of an oxygen sag curve following the discharge of combined sewage to the stream.

Figure 5-E June 28, 1977 2:50 to 4:20 PM
Wet weather stream flow (12.8 m^3/s) during rain (1.1 cm); combined sewer discharges.

Figure 5-F June 28, 1977 4:54 to 6:00 PM
Wet weather stream flow during rainfall; combined sewer discharges.

Figure 5-G & 5-H June 28, 1977 6:15 to 8:50 PM
Wet weather stream flow during rainfall; combined sewer discharges.

These results also demonstrate the development of an oxygen sag curve in the Hocking River following a combined sewer discharge.

Figure 5-I July 26, 1977 3:30 - 5:10 PM
Wet weather stream flow (3.34 m^3/s) during rain (1.07 cm); combined sewer discharges.

Figure 5-J July 26, 1977 6:55 to 8:15 PM
Wet weather stream flow; no combined sewer discharges.

Figure 5-K July 26, 1977 8:25 to 8:50 PM
Wet weather stream flow; no combined sewer discharges.

Figure 5-L July 26-27, 1977 11:10 PM to 12:25 AM
Wet weather stream flow; no combined sewer discharges.

Figure 5-M July 27, 1977 8:35 to 9:55 AM
Dry weather stream flow (2.15 m^3/s); no combined sewer discharges.

Figure 5-N July 27, 1977 12:30 AM - 1:45 PM
Dry weather stream flow; no combined sewer discharges.

These sequences of results show the gradual development of an oxygen sag curve and the start of the recovery of the dissolved oxygen levels following discharges of combined sewage from Lancaster to the Hocking River.

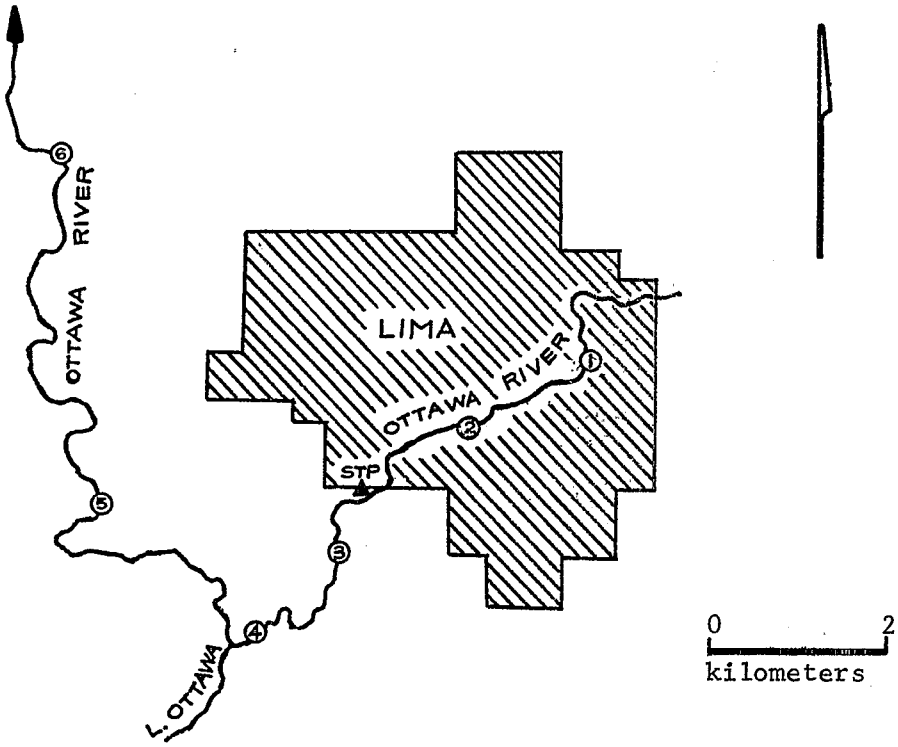
Recommendations

The use of Lancaster as a location for more extensive studies on the impacts of combined sewer discharges on receiving streams is recommended. The dissolved oxygen sag curves that develop in the Hocking River below Lancaster are very well defined and the amount of oxygen depletion indicates an impact. Accessibility to sampling sites in town is only fair and there are several streams to monitor. However, some of these sites could be eliminated in a more extensive sampling program. The accessibility of the downstream sites is excellent. A stream gaging station would have to be re-established.

Name LIMA
Location Allen County, Ohio

Population (year) 52,262 (1973)

Site Map



Receiving Streams

In town	Ottawa River
Downstream	Ottawa River Little Ottawa River (Trib. to Ottawa R. @ +3.2 kms)

Sampling Sites

No.	Stream	River Location kms	River Location miles	Description
1	Ottawa R.	-4.0	-2.5	Lover's Lane
2	"	-2.1	-1.3	Metcalf St. Br.
Ref	"	0.0	0.0	STP
3	"	1.0	0.6	Adgate Rd. Br.
4	"	3.2	2.0	Shawnee Rd. Br.
5	"	7.2	4.5	SR 117 Br.
6	"	14.4	9.0	Allentown Rd. Br.

Combined Sewer Outfalls

Stream	No.	River Locations
Ottawa R.	5	-4.0 to -1.8 kms

Stream Gages

Stream	Gage No.	Location	Type	Operator
Ottawa R.	04187500	Allentown Rd.	Flow/Quality	USGS

Accessibility of Sampling Sites

The accessibility of the sampling sites is poor to fair. While there is only one stream to sample and most of the sampling sites are at bridge crossings, the route between the downstream sites is heavily industrialized and is often congested with traffic.

Other Available Information

Stormwater Overflow Study, Lima, Ohio by Floyd G. Brown and Associates, Ltd., Marion, Ohio, 1973.

Sewage Treatment Plant

Superintendent:	Roland Nabergoll
Address:	1200 South Collett Street Lima, Ohio 45804
Phone:	419-228-6731

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
6-A	6/29/77 9:55 - 11:00 AM	Dry weather stream flow (2.12 m^3/s); no combined sewer discharges.
6-B	6/30/77 12:10 - 12:50 PM	Wet weather stream flow during rainfall (4.7 cm); combined sewer discharges.
6-C	7/1/77 9:45 - 10:25 AM	Wet weather stream flow (16.2 m^3/s) following rainfall on preceding day; combined sewer discharges.

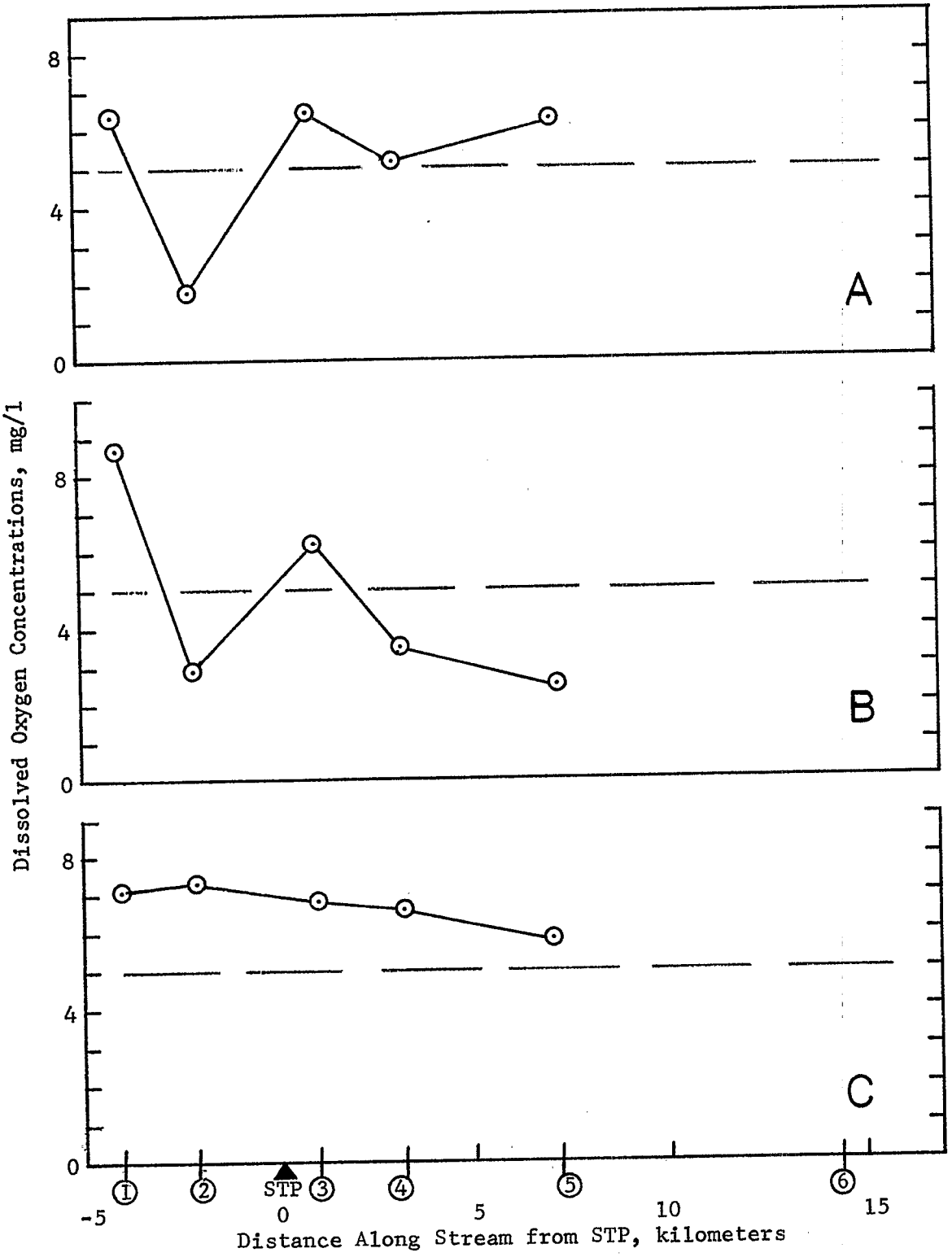


Figure 6. Dissolved oxygen profiles - Lima.

Analysis of Results

Figure 6-A June 29, 1977 9:55 to 11:00 AM
Dry weather stream flow (2.12 m^3/s); no combined sewer discharges.

Figure 6-B June 30, 1977 12:10 to 11:50 PM
Wet weather flow during rainfall (4.7 cm); combined sewer discharges.

Figure 6-C July 1, 1977 9:45 to 10:25 AM
Wet weather stream flow (16.2 m^3/s) following rainfall on preceding day; combined sewer discharges.

This series of graphs illustrates some of the impacts that the discharge of combined sewage from Lima has on the Ottawa River. Following the rainfall on June 30 (Figure 6-B), the dissolved oxygen levels in the stream above the sewage treatment plant are increased by the addition of surface runoff, while those below the plant are reduced. Subsequently, the values gradually return to normal (Figure 6-C). The low dissolved oxygen values at Sampling Site Number 2 are thought to be caused by an industrial waste discharge in town.

Recommendations

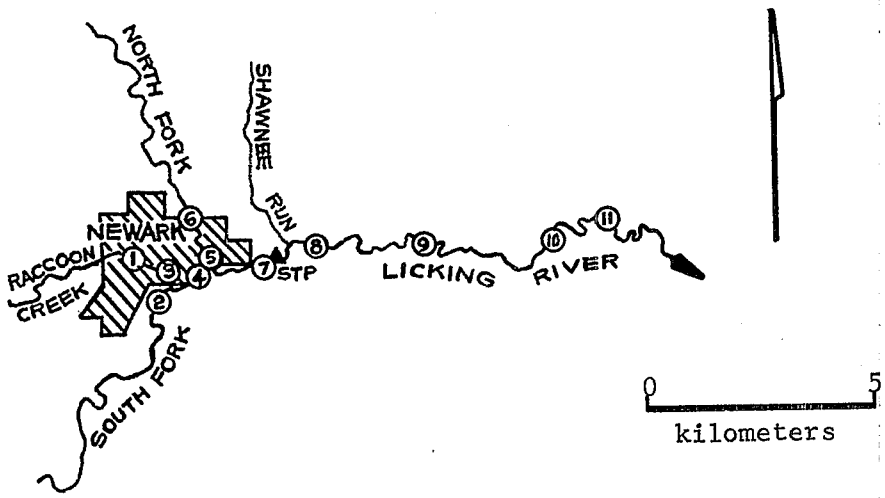
As noted earlier in the report, Lima is in the process of constructing an interception/storage system for its combined sewer outfalls. When this system is operational there will be only limited discharges to the Ottawa River from the combined sewer system. Thus the site will no longer be suitable for more extended studies on the impacts of the discharge from combined sewer outfalls to the receiving stream.

Name NEWARK

Location Licking County, Ohio

Population (year) 42,351 (1973)

Site Map



Receiving Streams

In town: North Fork Licking River & South Fork Licking River (form Licking River @ -2.2 kms)
Raccoon Creek (Trib. to S. Fork Licking R. @ -2.0 kms)

Downstream: Licking River

Sampling Sites

No.	Stream	River Location kms	River Location miles	Description
1	Raccoon C.	-2.4	-1.5	21st St. Br.
2	S. Fork Licking R.	-2.7	-1.7	Orchard St. Br.
3	Raccoon	-0.5	-0.3	Wilson Rd. Br.
4	S. Fork Licking R.	-0.5	-0.3	2nd St. Br.
5	N. Fork Licking R.	-0.2	-0.1	Ohio St. Br.
6	"	-2.7	-1.7	Manning Rd. Br.
7	Licking R.	-0.2	-0.1	Above STP
Ref	"	0.0	0.0	STP
8	"	2.9	1.8	Staddens Rd. Br.
9	"	8.0	5.2	Claylick Rd. Br.
10	"	16.1	10.0	Toboso Rd. Br.
11	"	22.9	14.3	Nashport Rd. Br.

Combined Sewer Outfalls

Stream	No.	River Locations
S. Fork Licking R.	4	In town
Raccoon Creek	12	"
N. Fork Licking R.	11	"
Others	13	-------

Stream Gages

Stream	Gage No.	Location	Type	Operation
S. Fork Licking R.	03145000	Hebron, Ohio	Flow	USGS
N. Fork Licking R.	03146000	Utica, Ohio	Flow	USGS
Licking R.	03146500	Staddens Rd. Br.	Flow/Quality	USGS

Accessibility of Sampling Sites

The accessibility of the sampling sites is good. Newark is a fairly large town with rush hour congestion. There are several sampling sites in town and there are three streams to monitor. All sampling sites are at bridge crossings and there is very good access to the downstream locations from a highway which parallels the receiving stream.

Other Available Information

None found.

Sewage Treatment Plant

Superintendent: Ray Nelson
Address: 1003 E. Main Street
Newark, Ohio 43055
Phone: 614-345-7334

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
7-A	6/16/77 5:00 - 6:35 AM	Dry weather stream flow (3.60 m^3/s); no combined sewer discharges.
7-B	6/16/77 10:30 AM - 1:00 PM	Dry weather stream flow; no combined sewer discharges.
7-C	6/17/77 4:25 - 5:35 AM	Dry weather stream flow (3.99 m^3/s); no combined sewer discharges.
7-D	7/12/77 6:10 - 8:30 AM	Wet weather stream flow (10.2 m^3/s) during moderate rainfall (3.8 cm); combined sewer discharges.
7-E	7/12/77 3:00 - 5:00 PM	Wet weather stream flow; no combined sewer discharges.
7-F	7/12/77 9:50 - 12:00 PM	Wet weather stream flow; no combined sewer discharges.
7-G	7/13/77 6:00 - 7:50 AM	Wet weather stream flow (23.3 m^3/s) following rainfall on preceding day; no combined sewer discharges.
7-H	7/21/77 1:35 - 4:10 PM	Wet weather stream flow (4.70 m^3/s) during rainfall (1.4 cm); prior to combined sewer discharges.
7-I	7/21/77 10:00 - 12:00 PM	Wet weather stream flow; combined sewer discharges.
7-J	7/22/77 1:05 - 3:30 AM	Wet weather stream flow (18.7 m^3/s) following rain on preceding day; no combined sewer discharges.
7-K	7/22/77 11:25 - 1:45 PM	Wet weather stream flow; no combined sewer discharges.

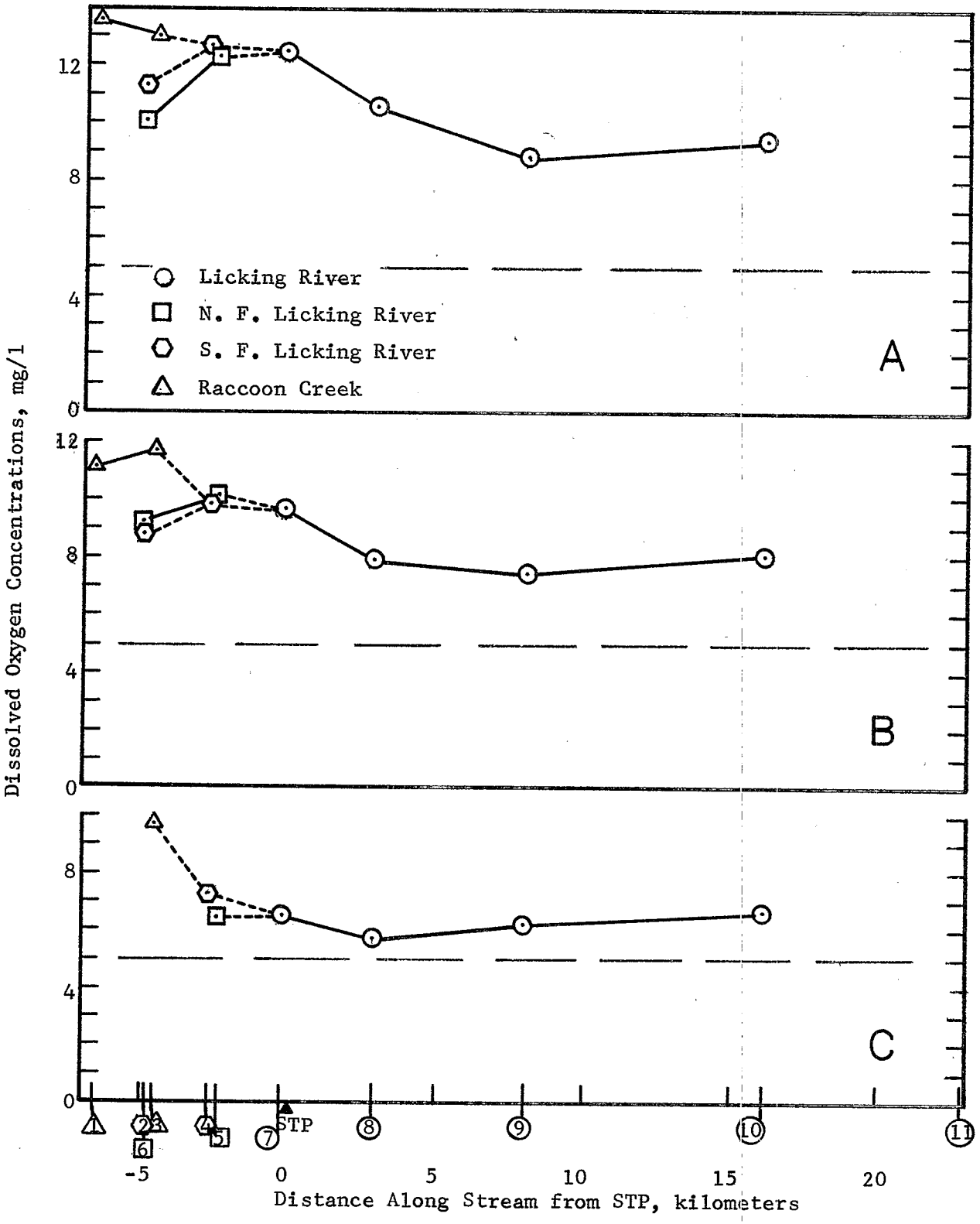


Figure 7. Dissolved oxygen profiles - Newark.

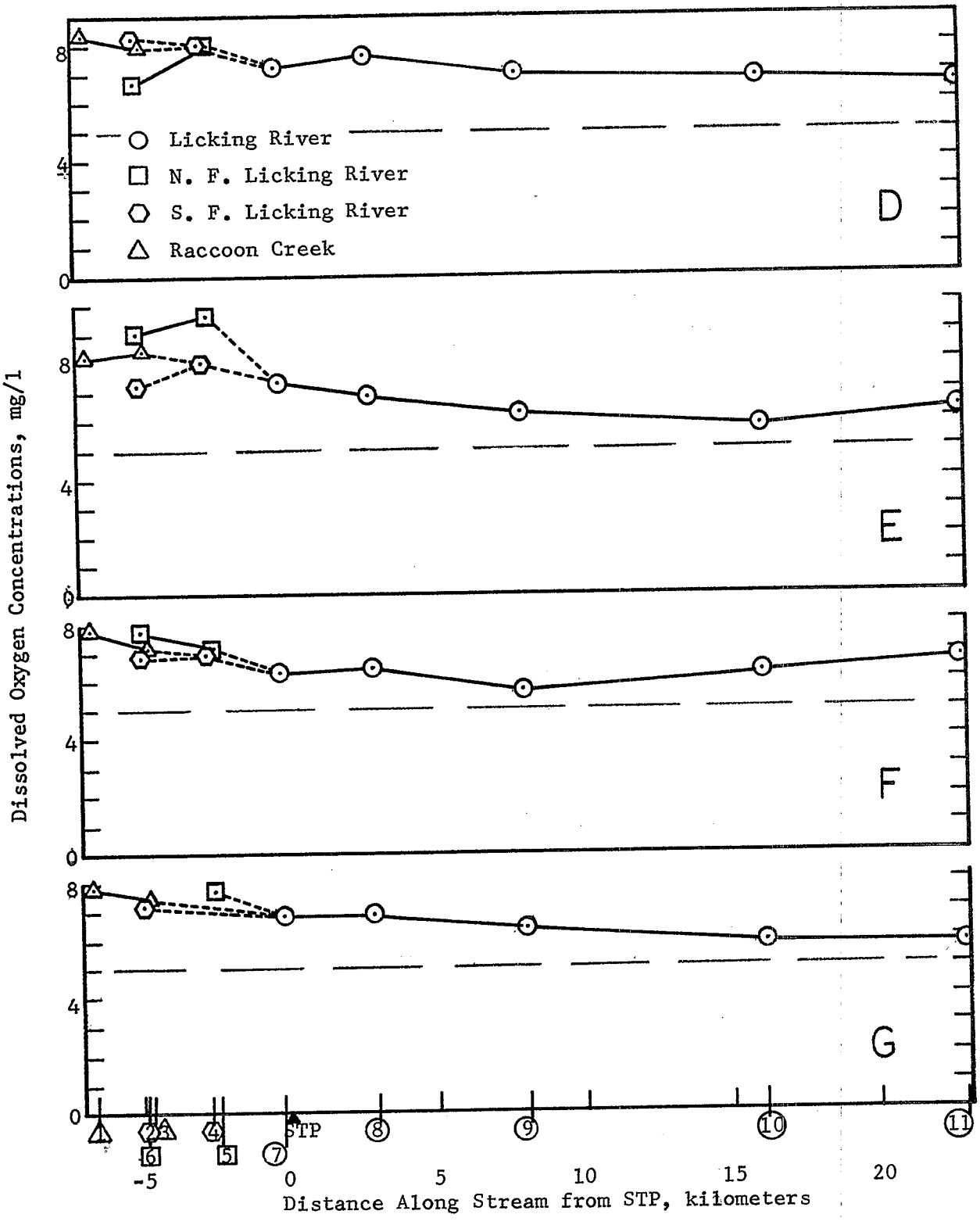


Figure 7. Dissolved oxygen profiles - Newark.

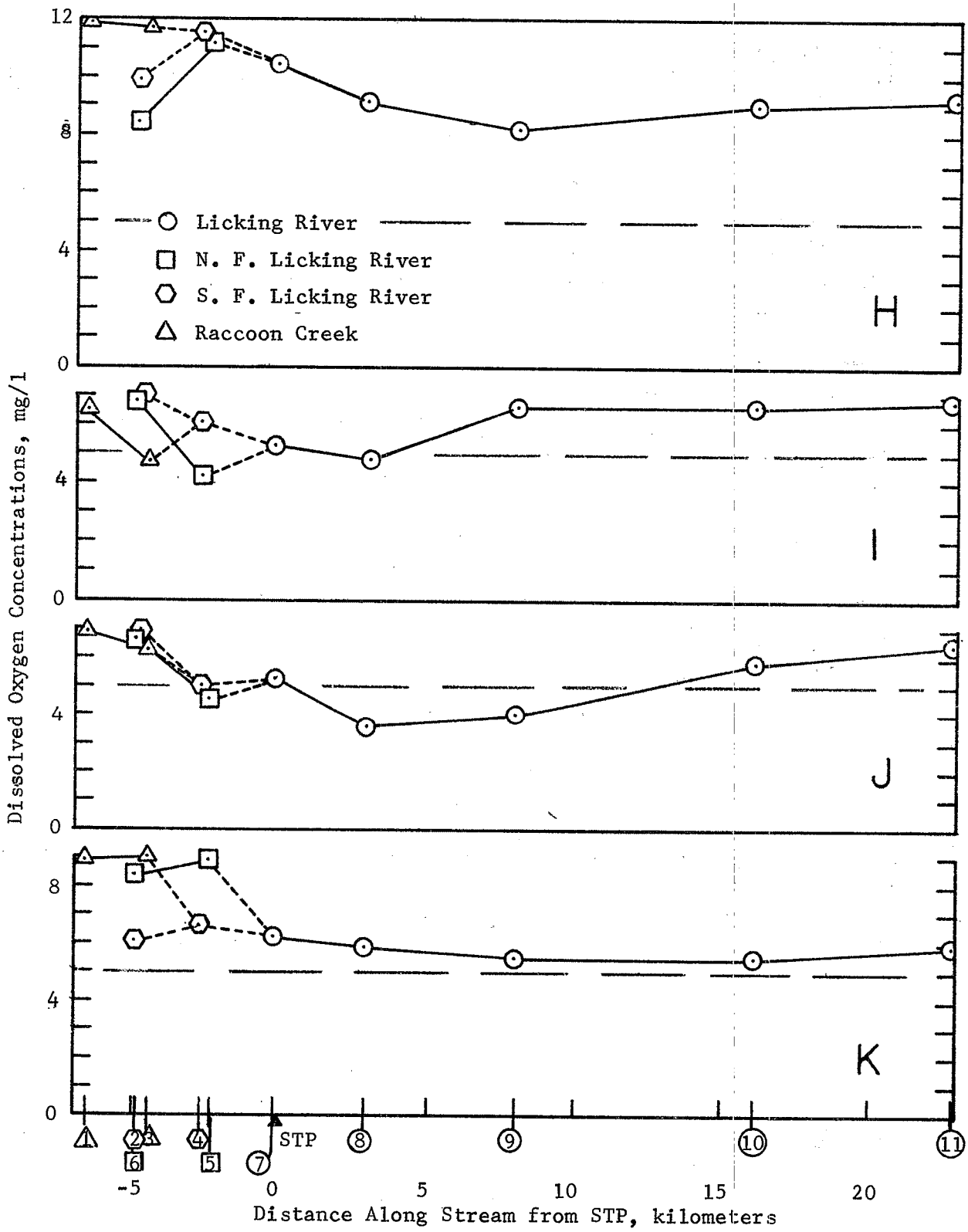


Figure 7. Dissolved oxygen profiles - Newark.

Analysis of Results

Figure 7-A June 16, 1977 5:00 to 6:35 AM
Dry weather stream flow (3.60 m^3/s); no combined sewer discharges.

Figure 7-B June 16, 1977 10:30 AM to 1:00 PM
Dry weather stream flow; no combined sewer discharges.

Figure 7-C June 17, 1977 4:25 to 5:35 AM
Dry weather stream flow (3.99 m^3/s); no combined sewer discharges.

This set of figures shows the dissolved oxygen levels in the Licking River and its tributaries in Newark during dry weather conditions. The values of the dissolved oxygen in the tributaries in town are relatively high, but there is some lessening of the water quality in the Licking River caused by the effluent from the sewage treatment plant.

Figure 7-D July 12, 1977 6:10 to 8:30 AM
Wet weather stream flow (10.2 m^3/s) during moderate rainfall (3.8 cm); combined sewer discharges.

Figure 7-E July 12, 1977 3:00 to 5:00 PM
Wet weather stream flow; no combined sewer discharges.

Figure 7-F July 12, 1977 9:50 to 12:00 PM
Wet weather stream flow; no combined sewer discharges.

Figure 7-G July 13, 1977 6:00 to 7:50 AM
Wet weather stream flow (23.3 m^3/s) following rainfall on preceding day; no combined sewer discharges.

This series of results, for wet weather flow conditions following a combined sewer discharge, shows a decrease in the dissolved oxygen levels in the tributaries in town and some impact on the Licking River downstream of town.

Figure 7-H July 21, 1977 1:35 to 4:10 PM
Wet weather stream flow (4.70 m^3/s) during rainfall (1.4 cm); prior to combined sewer discharges.

Figure 7-I July 21, 1977 10:00 to 12:00 PM
Wet weather stream flow; combined sewer discharges.

Figure 7-J July 22, 1977 1:05 to 3:30 AM
Wet weather stream flow (18.7 m^3/s) following rain on preceding day; no combined sewer discharges.

Figure 7-K July 22, 1977 11:25 AM to 1:45 PM
Wet weather stream flow; no combined sewer discharges.

This series of results shows the oxygen conditions in the streams prior to the discharge of the combined sewers (Figure 7-H); the subsequent lessening of these values following combined sewer discharges (Figures 7-I and 7-J); and the start of the recovery of oxygen values as the flow begins to return to dry weather conditions (Figure 7-K).

Recommendations

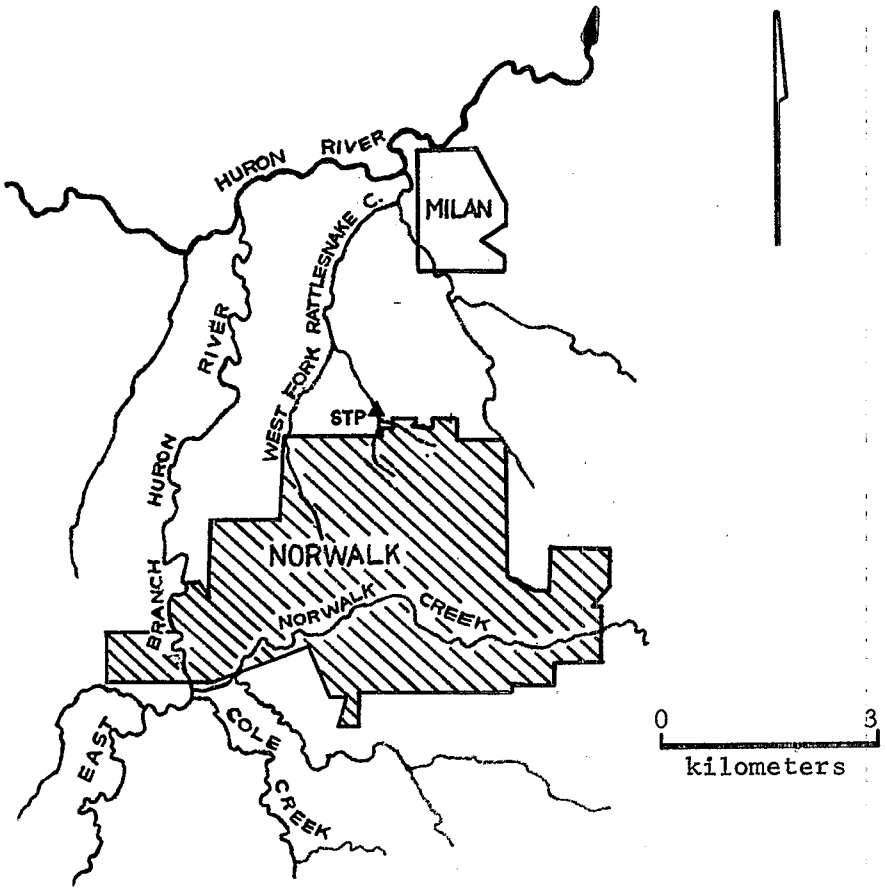
The town of Newark is recommended as a location for expanded studies on the impacts that combined sewer discharges have on receiving waters. While there are several streams to monitor at this site and accessibility is only good, there is a well defined impact on the dissolved oxygen levels in the Licking River from combined sewer outfalls in the town. There are several stream gages in the vicinity and the cooperation provided by the superintendent of the sewage treatment plant is excellent.

Name NORWALK

Location Huron County, Ohio

Population (year) 13,624 (1973)

Site Map



Receiving Streams

In town

Norwalk Creek (Trib. to East Branch Huron River) (South of town)
West Fork Rattlesnake Creek (Trib. to Rattlesnake Creek) (North of town)
East Fork Rattlesnake Creek (Trib. to Rattlesnake Creek) (North of town)

Downstream

East Branch of Huron River (Trib. to Huron River)
Rattlesnake Creek (Trib. to Huron River)
Huron River

Sampling Sites

None selected.

Combined Sewer Outfalls

Stream	No.	Location
Norwalk Creek	1	Pump Station @ Pleasant St.
West Fork Rattlesnake C.	1	Washington & Hester Sts.
East Fork Rattlesnake C.	3	Lake Ave. & Republic St.
		Cline Ave. & Millan St.
		STP overflow

Stream Gages

Stream	Gage No.	Location	Type	Operation
Huron R.	04199000	Milan, Ohio	Flow	USGS

Sewage Treatment Plant

Superintendent:	Charles Sweet
Address:	4563 Old Plank Rd.
	Norwalk, Ohio 44857
Phone:	419-668-2039

Summary of Field Determinations

No field studies were conducted.

Recommendations

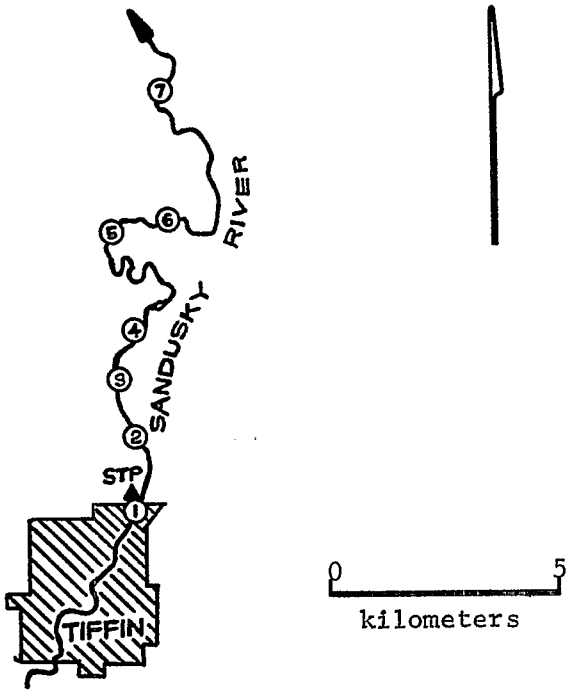
The stream drainage pattern in Norwalk is quite complex. There are several small streams in and around the town that are used to collect combined sewage discharges. Each of these streams in turn flow only a short distance from the outfalls before they join to form larger streams. As a consequence, a field sampling program was not initiated in Norwalk; and the use of this town for further field studies is not recommended.

Name TIFFIN

Location Seneca County, Ohio

Population (year) 21,073 (1973)

Site Map



Receiving Stream

In town	Sandusky River
Downstream	Sandusky River

Sampling Sites

No.	Stream	River Locations kms	River Locations miles	Description
1	Sandusky R.	-0.8	-0.5	Huss St. Br.
Ref	"	0.0	0.0	STP
2	"	1.9	1.2	Opposite Hyter Rd.
3	"	3.7	2.3	C.R. 38 Br.
4	"	5.3	3.3	Issac Walton
5	"	11.1	6.9	Fort Seneca Br.
6	"	12.2	7.6	Abbotts Rd. Br.
7	"	20.8	12.9	Old Fort Br.

Combined Sewer Outfalls

Stream	No.	River Location
Sandusky R.	Unknown	Unknown

Stream Gages

Stream	Gage No.	Location	Type	Operation
Sandusky R.	04197000	At -11.5 kms	Flow	USGS
"	04196990	At -15.0 kms	Quality	Discontinued
"	04198000	At +29.0 kms	Flow	USGS

Accessibility of Sampling Sites

The accessibility of the sampling sites in Tiffin is good. There is only one stream to monitor and travel downstream of the town is very easy. However, not all of the sampling locations are at bridge crossings and access to the river is often difficult.

Other Available Information

None found.

Sewage Treatment Plant

Superintendent:	Gene Feasel
Address:	961 N. Water Street Tiffin, Ohio 44883
Phone:	419-447-9157

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
9-A	6/30/77 5:10 - 6:40 PM	Wet weather stream flow (1.16 m^3/s) with rainfall (2.8 cm); combined sewer discharges.
9-B	7/1/77 7:00 - 8:00 AM	Wet weather stream flow (20.9 m^3/s) following rainfall on preceding day; combined sewer discharges.
9-C	7/1/77 2:00 - 2:55 PM	Wet weather stream flow; no combined sewer discharges.

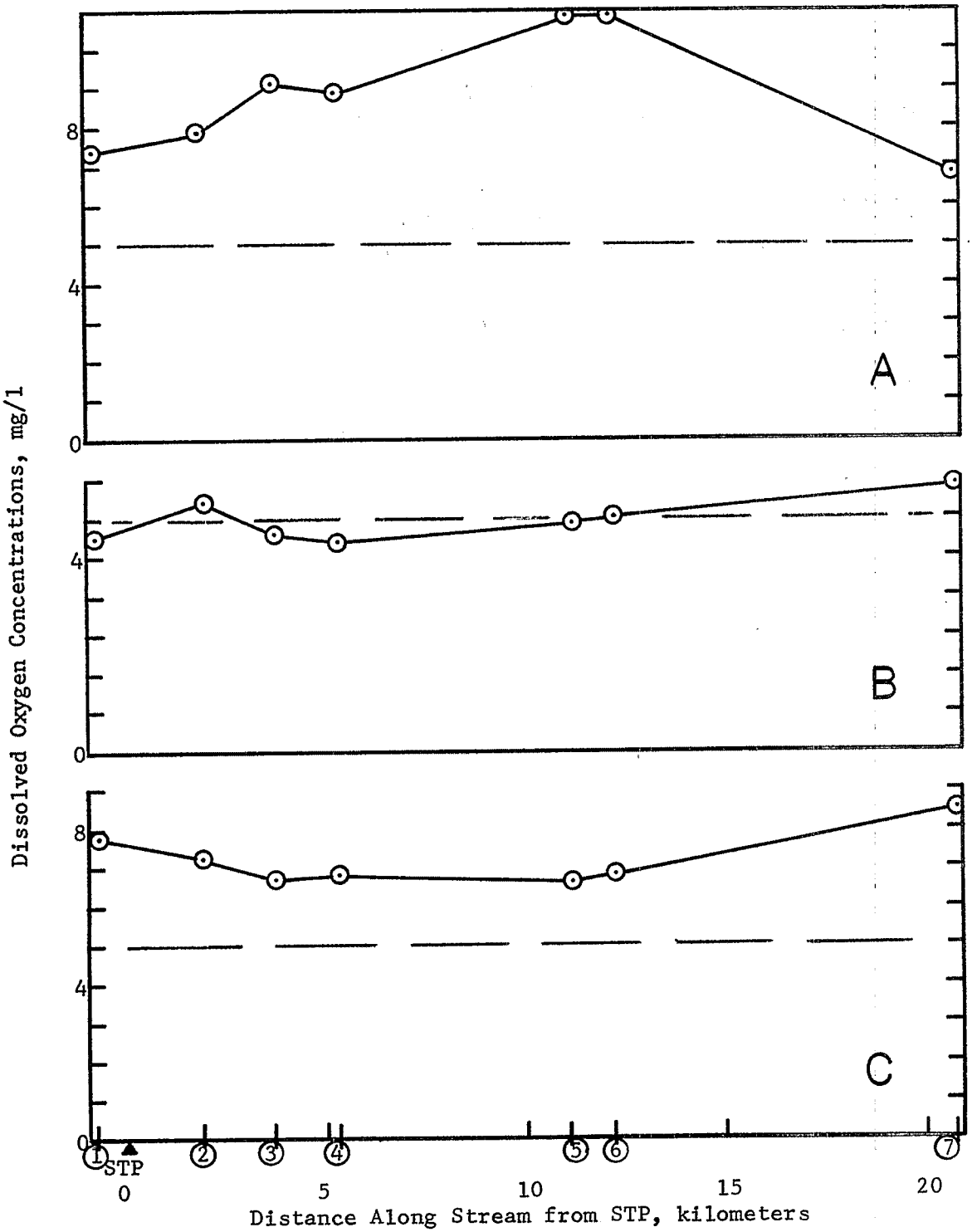


Figure 9. Dissolved oxygen profiles - Tiffin.

Analysis of Results

Figure 9-A June 30, 1977 5:10 to 6:40 PM
Wet weather stream flow (1.16 m^3/s) with rainfall (2.8 cm); combined sewer discharges.

Figure 9-B July 1, 1977 7:00 to 8:00 AM
Wet weather stream flow (20.9 m^3/s) following rainfall on preceding day; combined sewer discharges.

Figure 9-C July 1, 1977 2:00 to 5:00 PM
Wet weather stream flow; no combined sewer discharges.

This sequence of figures shows the minimal impact that combined sewage discharges from Tiffin have on the Sandusky River. While the dissolved oxygen levels in the river decrease following an overflow, the values do not drop below 4 mg/1, and the maximum variation over 20 kilometers of stream length does not exceed 1.5 mg/1.

Recommendations

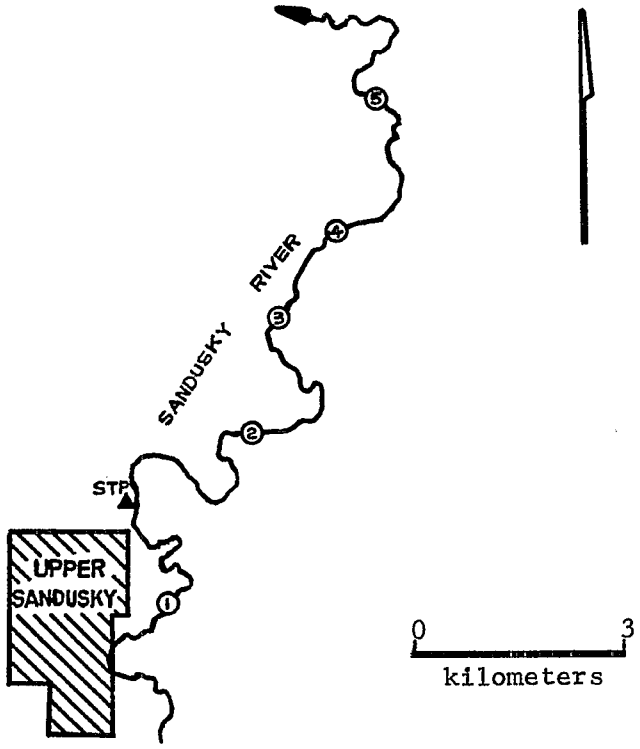
Because of the minimal impact that the combined sewer discharges from Tiffin have on the Sandusky River, the continued study of these impacts at this site is not recommended.

Name UPPER SANDUSKY

Location Wyandot County, Ohio

Population (year) 5,661 (1973)

Site Map



Receiving Stream

In town	Sandusky River
Downstream	Sandusky River

Sampling Sites

No.	Stream	River Locations kms	River Locations miles	Description
1	Sandusky R.	-3.2	-2.0	US Rt 30 N Br.
Ref	"	0.0	0.0	STP
2	"	3.0	1.9	S.R. 52 Br.
3	"	5.9	3.7	Indian Mill Br.
4	"	7.8	4.9	C.R. 44 Br.
5	"	10.6	6.6	C.R. 67 Br.

Combined Sewer Outfalls

Stream	No.	River Location
Sandusky R.	Unknown	Unknown

Stream Gages

Stream	Gage No.	Location	Type	Operation
Sandusky R.	04196500	S.R. 52	Quality	USGS

Accessibility of Sampling Sites

The accessibility of the sampling sites is excellent. Upper Sandusky is a very small town and there is only one stream to monitor. All of the sampling sites are at bridges, and travel between sites is very easily accomplished.

Other Available Information

None found.

Sewage Treatment Plant

Superintendent:	Dale Smith
Address:	Sewage Treatment Plant Upper Sandusky, Ohio 43351
Phone:	419-294-2252

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
10-A	7/1/77 9:20 - 9:45 AM	Wet weather stream flow (17.2 m^3/s) during heavy rainfall (7.5 cm); combined sewer discharges.
10-B	7/1/77 2:15 - 2:35 PM	Wet weather stream flow; combined sewer discharges.
10-C	7/1/77 10:10 - 10:35 PM	Wet weather stream flow; no combined sewer discharges.

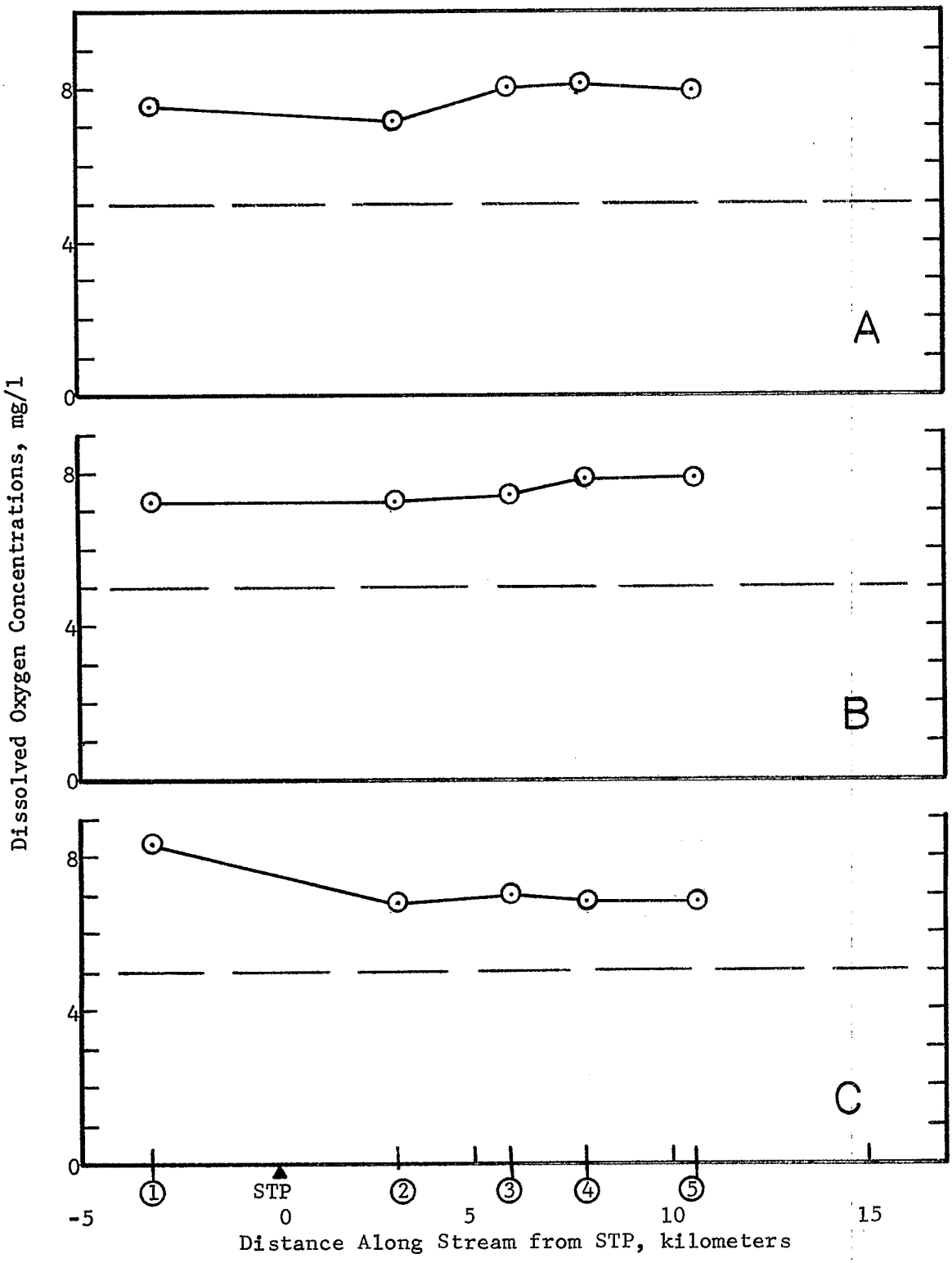


Figure 10. Dissolved oxygen profiles - Upper Sandusky.

Analysis of Results

Figure 10-A July 1, 1977 9:20 to 9:45 AM
Wet weather stream flow (17.2 m^3/s) during heavy rainfall (7.5 cm); combined sewage discharges.

Figure 10-B July 1, 1977 2:15 to 2:35 PM
Wet weather stream flow; combined sewer discharges.

Figure 10-C July 1, 1977 10:10 to 10:35 PM
Wet weather stream flow; no combined sewer discharges.

The sequence of figures indicates that the combined sewer discharges from the town of Upper Sandusky exert only a minimal effect on the dissolved oxygen levels in the Sandusky River, decreasing the values by only one mg/l at most of the sampling stations.

Recommendations

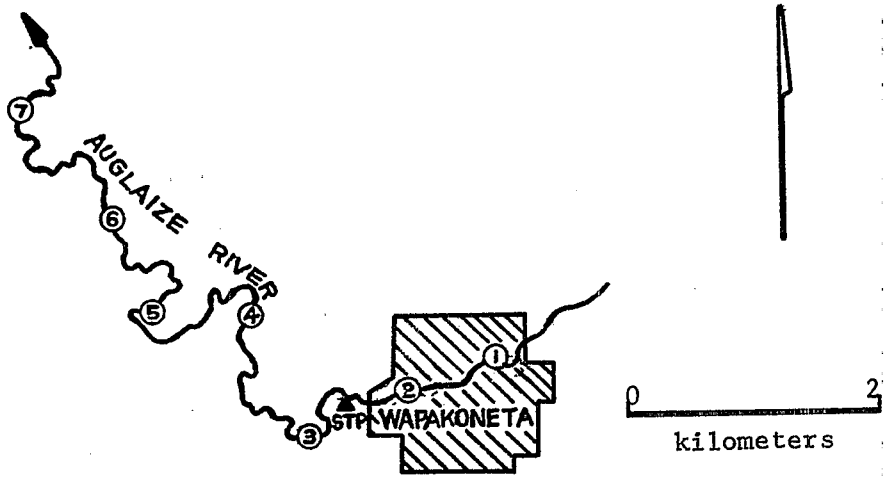
Because of the minimal impact exerted by the combined sewer discharges from Upper Sandusky on the Sandusky River, further studies at this location are not recommended.

Name WAPAKONETA

Location Auglaize County, Ohio

Population (year) 7,496 (1973)

Site Map



Receiving Stream

In town	Auglaize River
Downstream	Auglaize River

Sampling Sites

No.	Stream	River Location kms	River Location miles	Description
1	Auglaize R.	-2.1	-1.3	Water St. Br.
2	"	-0.8	-0.5	Mechanic St. Br.
Ref	"	0.0	0.0	STP
3	"	1.3	0.8	Greenlawn Cemetery (stones)
4	"	5.4	3.4	Glynwood R. (first turn)
5	"	7.1	4.4	Glynwood R. Br.
6	"	9.4	5.9	Fisher Rd. Br.
7	"	11.4	7.1	Kelly Rd. - no bridge

Combined Sewer Outfalls

Stream	No.	River Location
Auglaize R.	4	-2.2 to 0.0 kms

Steam Gages

None.

Accessibility of Sampling Sites

The accessibility of the sampling sites is fair to good. Wapakoneta is a relatively small town and there is little traffic congestion. There is only one stream to monitor; but there are few bridge crossings downstream of town, and the time required to make field measurements is excessive.

Other Available Information

None found.

Sewage Treatment Plant

Superintendent:	Richard Harshbarger
Address:	RFD No. 2 Herb Street Wapakoneta, Ohio 45895
Phone:	419-738-2418

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
11-A	8/15/77 11:10 AM - 12:25 PM	Wet weather stream flow during rainfall (2.2 cm); combined sewer discharges.
11-B	8/15/77 3:10 - 4:10 PM	Wet weather stream flow; combined sewer discharges.
11-C	8/15/77 8:15 - 9:15 PM	Wet weather stream flow; combined sewer discharges.
11-D	8/16/77 1:35 - 2:40 PM	Wet weather stream flow following rainfall on preceding day; no combined sewer discharges.

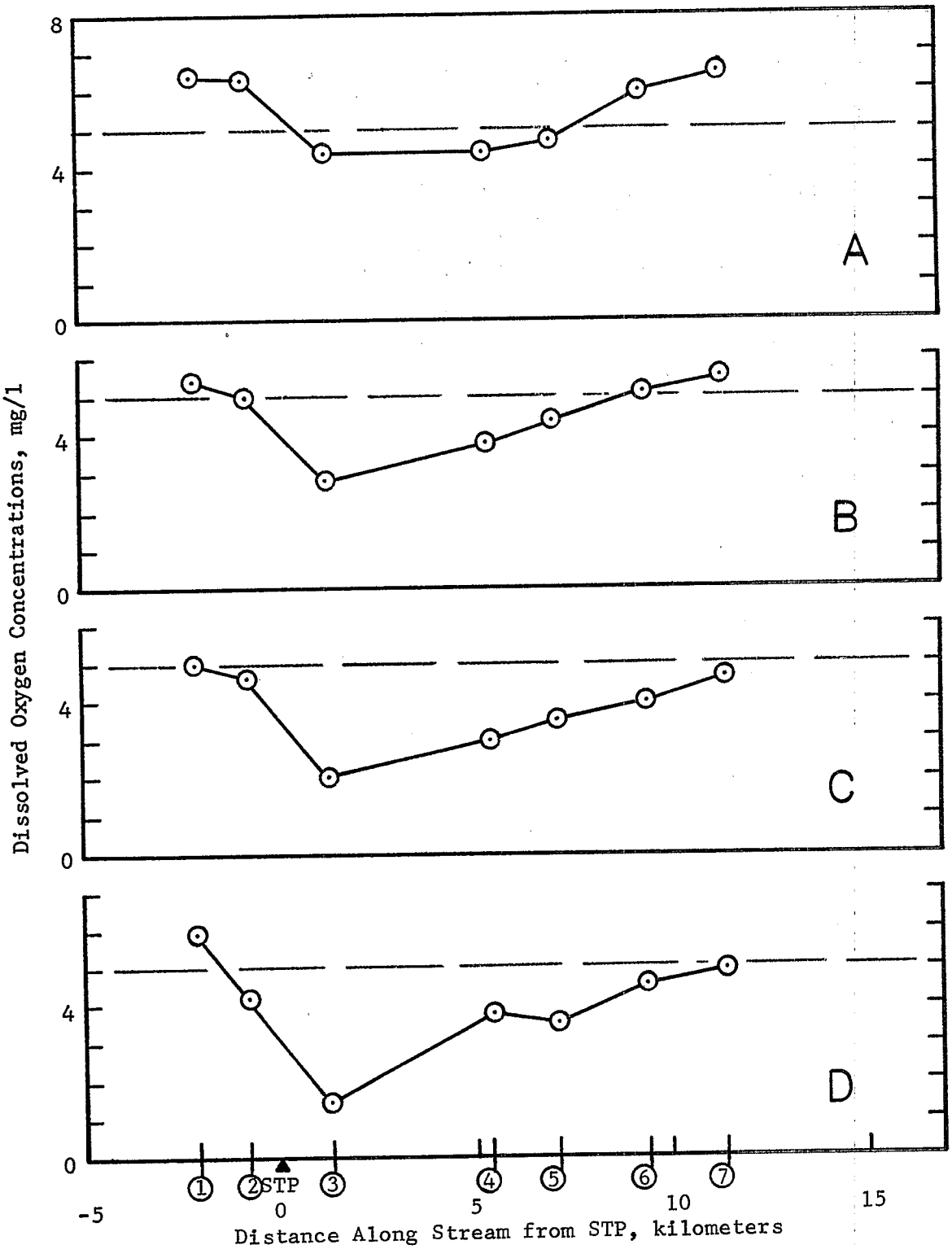


Figure 11. Dissolved oxygen profiles - Wapakoneta.

Analysis of Results

Figure 11-A August 15, 1977 11:10 AM to 12:25 PM
Wet weather stream flow during rainfall (2.2 cm); combined sewer discharges.

Figure 11-B August 15, 1977 3:10 to 4:10 PM
Wet weather stream flow; combined sewer discharges.

Figure 11-C August 15, 1977 8:15 to 9:15 PM
Wet weather stream flow; combined sewer discharges.

Figure 11-D August 16, 1977 1:35 to 2:40 PM
Wet weather stream flow following rainfall on preceding day; no combined sewer discharges.

This sequence of results, following a rainfall that caused the combined sewers in Wapakoneta to discharge, shows the progression of the impact of these discharges on the Auglaize River downstream of town and the beginning of the gradual recovery of the dissolved oxygen levels in the stream.

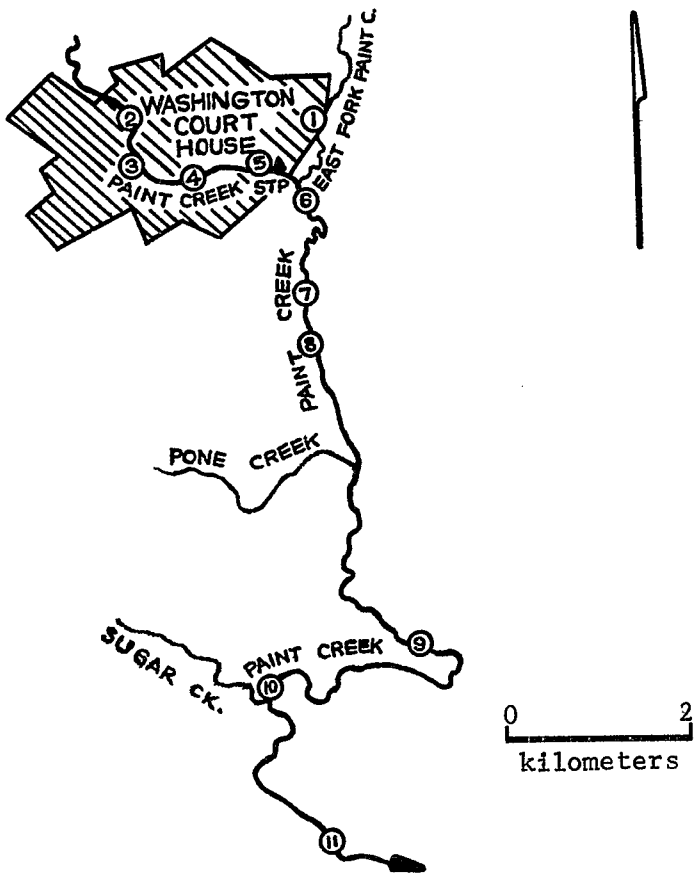
Recommendations

There is a clearly defined impact of the combined sewage discharges to the Auglaize River from the town of Wapakoneta. The accessibility of sampling sites is only fair to good because of the lack of river crossings downstream of town, but this condition is not too serious. There are no stream gages on the Auglaize River near the town, but this condition can also be corrected. Therefore it is recommended that Wapakoneta be considered for more extensive studies on the effects of combined sewer discharges.

Name WASHINGTON COURT HOUSE
Location Fayette County, Ohio

Population (year) 12,534 (1973)

Site Map



Sampling Sites

No.	Stream	River Locations kms	River Locations miles	Description
1	E. Fork Paint C.	-1.2	-0.7	U.S. Rt. 22 Br.
2	Paint Creek	-2.7	-1.7	Oakland St. Br.
3	"	-2.1	-1.3	Temple St. Br.
4	"	-1.1	-0.7	Fayette St. Br.
5	"	-0.2	-0.1	Elm St. Br.
Ref	"	0.0	0.0	STP
6	"	1.0	0.6	Robinson Rd. Br.
7	"	2.7	1.7	S. Fayette St. Br.
8	"	3.4	2.1	U.S. 35 Br.
9	"	9.3	5.8	Flakes Ford Rd. Br.
10	"	13.0	8.1	Sturgeon Mills Rd. Br.
11	"	16.1	10.0	Rock Mills Br.

Receiving Streams

In town	East Fork Paint Creek (Trib. to Paint Creek @ 0.7 kms) Paint Creek
Downstream	Paint Creek

Combined Sewer Outfalls

Stream	No.	River Locations
East Fork Paint C.	1	In town
Paint C.	31	"

Stream Gages

None.

Accessibility of Sampling Sites

The accessibility of the sampling sites is good. There are two streams to monitor in town, and the railroad crossings and traffic congestion can slow cross-town travel. All sampling sites are at bridge crossings and the accessibility of the downstream sites is very good.

Other Available Information

Report on combined sewer discharges from Bird and Bull, Ltd., Worthington, Ohio.

Sewage Treatment Plant

Superintendent:	Orvil Dixon
Address:	1110 S. Elm Street Washington C.H., Ohio 43160
Phone:	614-335-0960

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
12-A	8/29/77 7:15 - 9:15 PM	Dry weather stream flow; no combined sewer discharges.
12-B	8/31/77 6:40 - 8:15 AM	Dry weather stream flow following light rain (0.04 cm) on preceding day; no combined sewer discharges.
12-C	9/2/77 7:00 - 8:25 PM	Wet weather stream flow immediately following moderate rainfall (0.42 cm); combined sewer discharges.
12-D	9/2/77 9:20 - 10:50 PM	Wet weather stream flow; no combined sewer discharges.
12-E	9/3/77 6:50 - 7:50 AM	Wet weather stream flow following rainfall (0.21 cm) on preceding day; no combined sewer discharges.
12-F	9/3/77 10:40 - 12:00 AM	Wet weather stream flow; no combined sewer discharges.

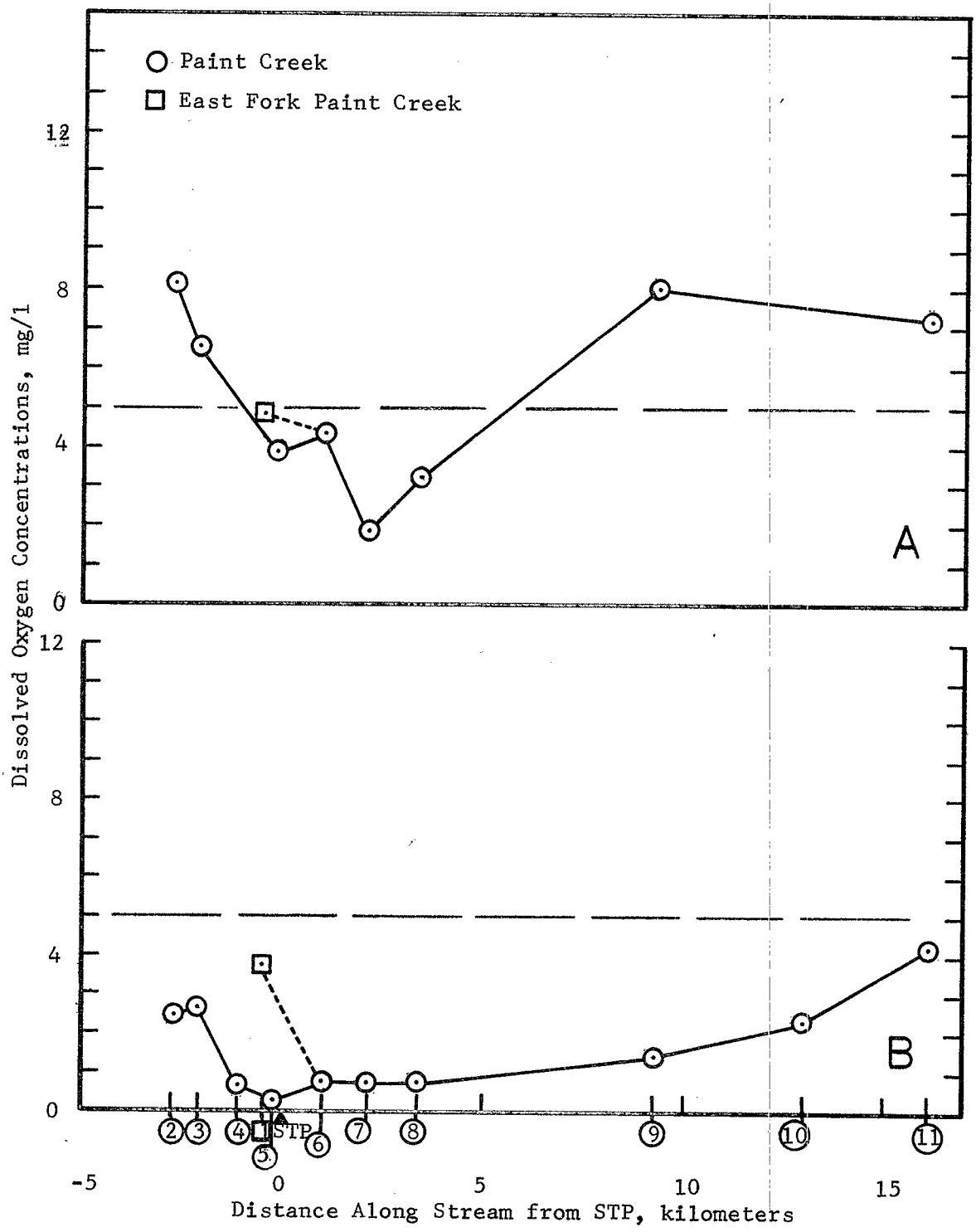


Figure 12. Dissolved oxygen profiles - Washington Court House.

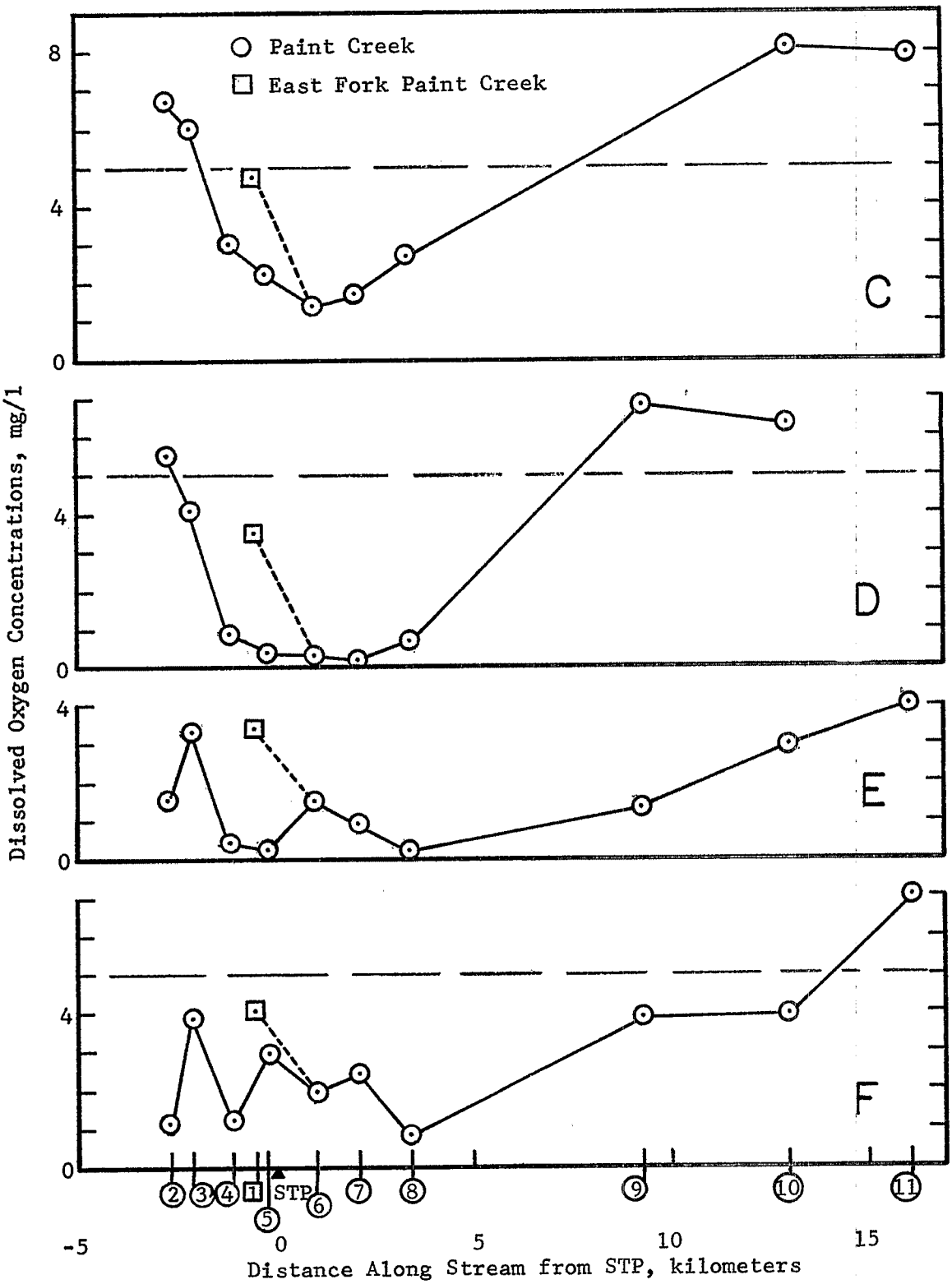


Figure 12. Dissolved oxygen profiles - Washington Court House.

Analysis of Results

Figure 12-A August 29, 1977 7:15 to 9:15 PM
Dry weather stream flow; no combined sewer discharges.

This figure illustrates the normal dry weather conditions in Paint Creek near Washington Court House. There is a gradual lessening of the dissolved oxygen levels along the stream as it flows through the town, apparently the result of industrial wastewater discharges. Following an additional impact at the sewage treatment plant, the stream recovers further downstream.

Figure 12-B August 31, 1977 6:40 to 8:15 AM
Dry weather stream flow following light rain (0.04 cm) preceding day; no combined sewer discharges.

Following a light rain, the dissolved oxygen levels in Paint Creek drop to values of nearly zero in town and cause values of less than 4 mg/l for nearly 10 kilometers downstream. However, because of lack of combined sewer discharge at this time, it is doubtful that this condition is the result of the impact of the rainfall and resulting runoff to the stream.

Figure 12-C September 2, 1977 7:00 to 8:25 PM
Wet weather stream flow immediately following moderate rainfall (0.42 cm); combined sewer discharges.

Figure 12-D September 2, 1977 9:20 to 10:50 PM
Wet weather stream flow; no combined sewer discharges.

Figure 12-E September 3, 1977 6:50 to 7:50 AM
Wet weather stream flow following rainfall on preceding day (0.21 cm); no combined sewer discharges.

Figure 12-F September 3, 1977 10:40 to 12:00 AM
Wet weather stream flow; no combined sewer discharges.

This sequence of graphs demonstrates the impacts to and the gradual recovery of the dissolved oxygen levels in Paint Creek following a combined sewer discharge.

Recommendations

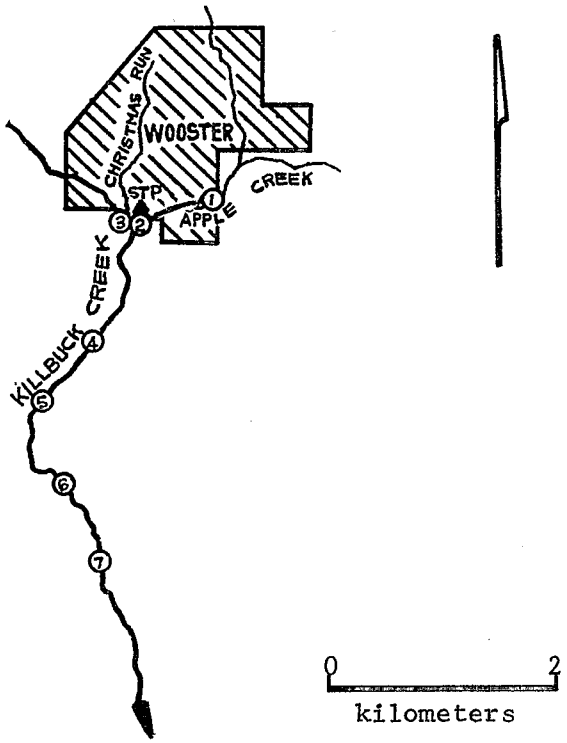
While the impacts from the combined sewer discharges in Washington Court House to Paint Creek can be documented, the continual lessening of dissolved oxygen levels from industrial wastewater discharges in the town may complicate any analysis of the combined sewer overflow problem, and further studies at this site are not recommended.

Name WOOSTER

Location Wayne County, Ohio

Population (year) 19,420 (1973)

Site Map



Receiving Streams

In town	Christmas Run (Trib. to Killbuck C. @ -0.1 kms) Little Apple Creek (Trib. to Apple C. @ -6.0 kms) Apple Creek (Trib. to Killbuck C.. @ 0.2 kms) Killbuck Creek
Downstream	Killbuck Creek

Sampling Sites

No.	Stream	River Location kms	River Location miles	Description
1	Apple Creek	-2.9	-1.8	Pittsburg Ave. Br.
Ref	"	0.0	0.0	STP
2	"	0.2	0.1	S.R. 95 Br.
3	Killbuck Creek	0.2	0.1	"
4	"	6.2	3.9	Twp. Rd. 49 Br.
5	"	8.5	5.3	Twp. Rd. 228 Br.
6	"	11.6	7.2	C.R. 76 Br.
7	"	15.8	9.8	Twp. Rd. 1 Br.

Combined Sewer Outfalls

Stream	No.	River Location
Apple Creek	3	Freeland Rd., Elm St. and STP
Christmas Run	1	Near STP

Stream Gages

None.

Accessibility of Sampling Sites

The accessibility of the sampling sites in the town of Wooster is good. The distance to the first available site below town is rather long, but travel is relatively easy. There are only gravel roads to the sites further downstream and these are often flooded following a heavy rain.

Other Available Information

None found.

Sewage Treatment Plant

Superintendent:	Tony Cantanzarite
Address:	Columbus Road Wooster, Ohio 44691
Phone:	216-264-7078

Summary of Field Determinations

Figure Number	Date/Times	Field Conditions
13-A	7/14/77 7:40 - 9:00 AM	Dry weather stream flow; no combined sewer discharges.
13-B	7/22/77 6:20 - 6:50 AM	Wet weather stream flow during rainfall (8.97 cm); combined sewer discharges.
13-C	8/10/77 8:00 - 9:50 AM	Dry weather stream flow; no combined sewer discharges.

Analysis of Results

Figure 13-A July 14, 1977 7:40 to 9:00 AM
Dry weather stream flow; no combined sewer discharges.

Figure 13-B July 22, 1977 6:20 to 6:50 AM
Wet weather stream flow during rainfall (8.97 cm); combined sewer discharges.

Figure 13-C August 10, 1977 8:00 to 9:50 AM
Dry weather stream flow; no combined sewer discharges.

This series of figures shows the dissolved oxygen levels in Killbuck Creek below Wooster for two conditions of stream flow. Figure 13-A and Figure 13-C are indicative of dry weather flow conditions and show a gradual decrease in the oxygen levels below the town, apparently caused by non-point discharges of materials leached from a large swamp through which Killbuck Creek flows. Figure 13-B, which is indicative of wet weather flow conditions, shows a similar decrease in dissolved oxygen levels along the length of the creek although the magnitudes of the values are much lower. This condition is apparently caused by the drainage of flood waters which inundated the swamp during the wet weather period.

Recommendations

Because of the impacts that the drainage from the swamp downstream of Wooster exerts on the dissolved oxygen levels in Killbuck Creek, the use of this location for additional studies on combined sewer overflows is not recommended.

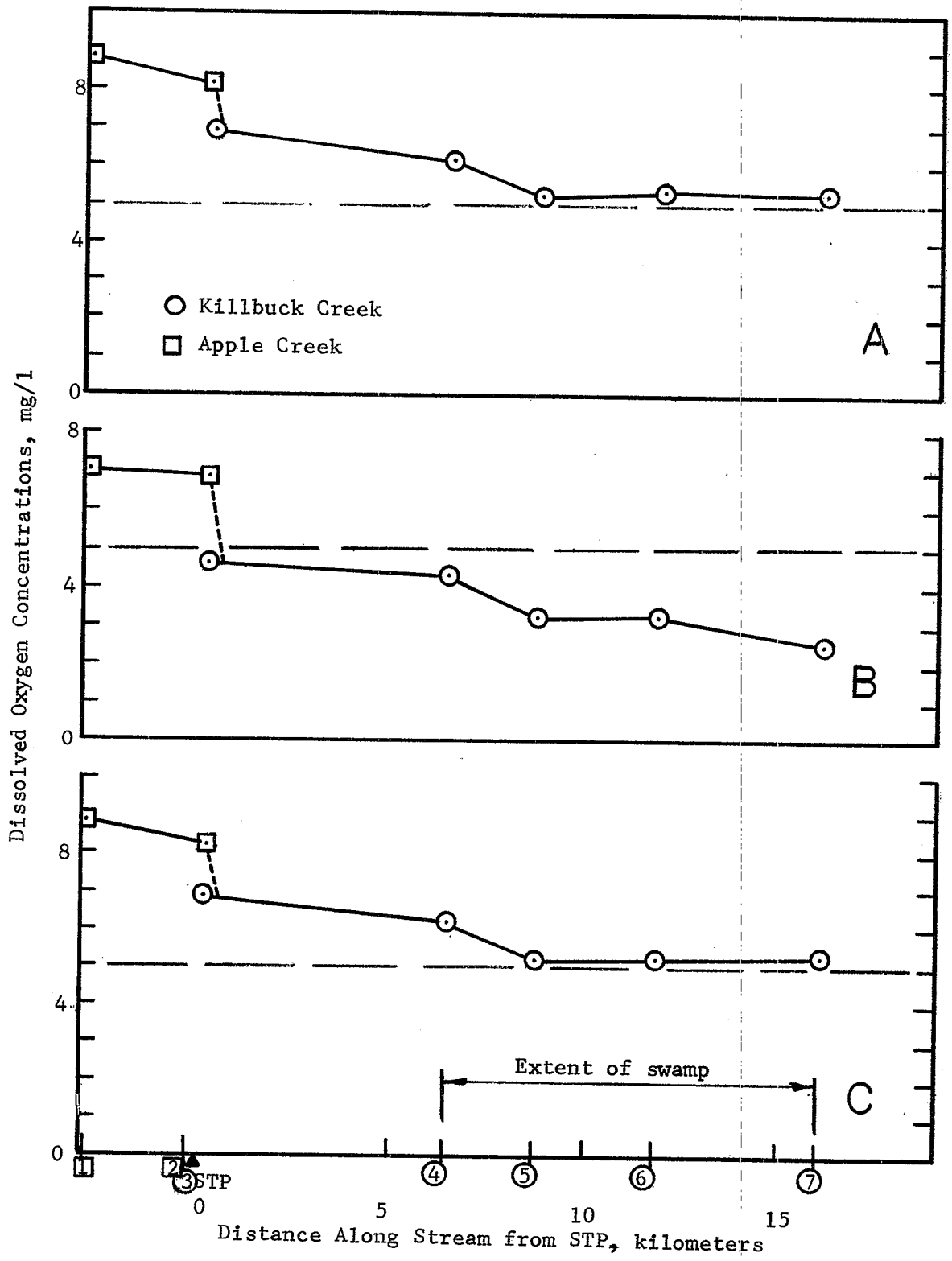


Figure 13. Dissolved oxygen profiles - Wooster.

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16. ABSTRACT

Thirteen towns and cities in Ohio, situated on streams and rivers having different mean daily flow rates, were investigated during the summer and spring of 1977 to determine their suitability as sites for more extensive field studies on the impacts of urban runoff on dissolved oxygen (D. O.) levels in the streams. The towns included Akron, Bucyrus, Delphos, Findlay, Lancaster, Lima, Newark, Norwalk, Tiffin, Upper Sandusky, Wapakoneta, Washington Court House and Wooster. Among factors considered in the selection process were a demonstrable impact of the urban runoff on D. O. levels, accessibility to stream sampling locations, and the availability of stream and precipitation gages.

Sites were rejected because (1) poor quality effluents from municipal and industrial treatment plants masked the impacts of combined sewer overflows (CSOs); (2) stream drainage pattern was too complex to monitor; or (3) impacts of the CSOs did not decrease the D. O. to less than 5 mg/l. Only the towns of Lancaster, Newark and Wapakoneta satisfactorily met the criteria established to qualify them as locations for more extensive field studies.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Dissolved Oxygen *Surface Water Runoff Combined Sewers Water Pollution *Water Quality	Urban Runoff	13B

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