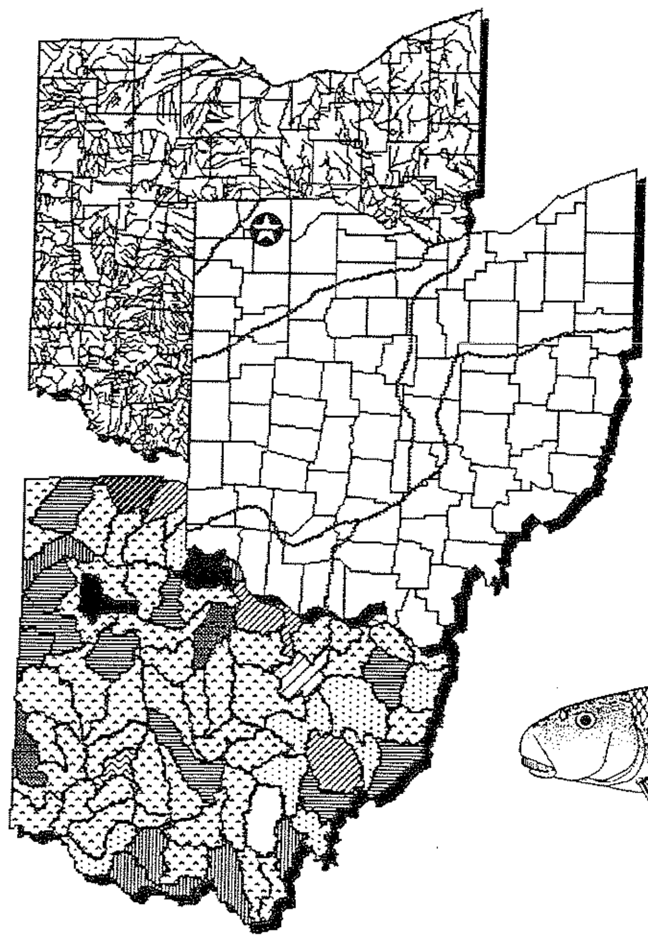
File Copy

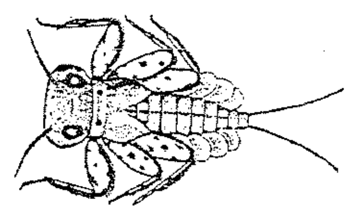
Ohio EPA
State of Ohio
Environmental Protection Agency

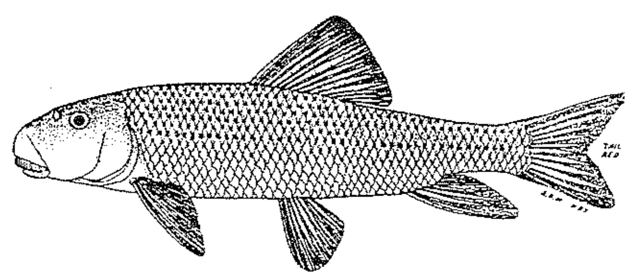
Ecological Assessment Section
Division of Surface Water

Biological and Water Quality Study of the Tiffin River and Selected Tributaries

Fulton, Williams and Defiance Counties, Ohio







December 20, 1993

P.O. Box 1049, 1800 WaterMark Dr., Columbus, Ohio 43266-0149

Biological and Water Quality Study of the Tiffin River

Fulton, Williams, and Defiance Counties, Ohio

June 30, 1993

Ohio EPA Technical Report EAS/1993-12-5

prepared by

State of Ohio Environmental Protection Agency
Division of Water Quality Planning and Assessment
Ecological Assessment Section
1685 Westbelt Drive
Columbus, Ohio 43228
and
Nonpoint Source Management Section
1800 WaterMark Drive
Columbus, Ohio 43266-0149
and
Surface Water Section
347 North Dunbridge Road
Bowling Green, Ohio 43402

TABLE OF CONTENTS

NOTICE TO USERS

Ohio EPA adopted biological criteria into the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (Effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), both of which are based on fish, and for the Invertebrate Community Index (ICI), which is based on macroinvertebrates. Criteria for each index are specified for each of Ohio's five ecoregions, and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the chemical and whole effluent toxicity evaluation methods, figure prominently in the assessment of Ohio's surface water resources.

Several documents support the adoption of the biological criteria by outlining the rationale for using biological information, the specific methods by which the biocriteria were derived and calculated, the field methods by which sampling must be conducted, and the process for evaluating results. These documents are:

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Division of Water Quality Monitoring & Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring & Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989a. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1990a. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

These documents and this document can be obtained by writing to:

Ohio EPA - WQP&A
Ecological Assessment Section
1685 Westbelt Drive
Columbus, Ohio 43228
(614) 777-6264

Acknowledgements

The following Ohio EPA staff are acknowledged for their significant contribution to this report.

Study Area Description - Rich McClay
Pollutant Loadings - Bill Ash
Ambient Chemical Water and Sediment Quality - Bill Ash
Biological Assessment:
  Macroinvertebrate Community - Jack Freda
  Fish Community - Chuck Boucher
Data Management - Dennis Mishne and Ed Rankin
TSD Coordinator - Jack Freda
Reviewer(s) - All contributors, Jeff DeShon, Marc Smith, Chris Yoder, Tom Balduf

This evaluation and report would not have been possible without the assistance of the study team (Rich McClay, Bill Ash, Chuck Boucher, Jack Freda), the many full and part time staff in the field, and the chemistry analyses provided by the Ohio EPA Division of Environmental Services.

Biological and Water Quality Survey of the Tiffin River and Selected Tributaries (Fulton, Williams and Defiance Counties, Ohio)

Ohio Environmental Protection Agency
Division of Water Quality Planning and Assessment
1800 WaterMark Drive
Columbus, Ohio 43266-0149

Introduction

The 1992 Tiffin River mainstem study area extended from its source in Fulton county downstream to its confluence with the Maumee River (RM 48.4-0.9). Additional sampling was conducted in three tributaries that form the headwaters of the Tiffin River: Mill Creek (RM 8.0-1.8), Bean Creek (RM 2.3-2.2), and Old Bean Creek (RM 1.9-1.7).

Specific objectives of this evaluation were to:

1) monitor and assess chemical/physical water quality, biological communities and stream habitat conditions in the Tiffin River basin to determine the magnitude and extent of impacts from point and nonpoint sources of pollution and habitat alteration,

2) evaluate potential impacts associated with the minor (<1 mgd) Stryker municipal wastewater treatment plant (WWTP),

3) develop baseline water quality and biological information in conjunction with the significant, ongoing changes in agricultural land use in the upper watershed associated with nonpoint pollution projects designed to reduce sediment and nutrient loads to streams within the basin,

4) determine attainment status of current designated uses (aquatic life, recreation, water supply, etc.) and recommend changes in designation of use where appropriate, and

5) conduct water resource trend assessments for portions of the Tiffin River mainstem where significant amounts of historical data exist.

Previous Ohio EPA surveys in the Tiffin River drainage include an intensive 1984 biological and water quality study that included the mainstem from RMs 37.6-0.9 and several major tributaries. The 1984 survey did not include headwater streams in the Bean Creek and Mill Creek watersheds, both sampled in 1992.

The findings of this evaluation may factor into regulatory actions taken by Ohio EPA (e.g., NPDES permits, Director's Orders), the Ohio Water Quality Standards (OAC 3745-1), and eventually be incorporated into the State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Water Resource Inventory (305[b] report).

Summary

A biological and water quality study was conducted in the Tiffin River basin in 1992 to 1) collect additional biological, physical habitat and chemical water quality data, 2) evaluate potential impacts associated with the predominantly nonpoint pollution sources in the basin (i.e., agricultural runoff, spills, hydromodification, etc.), 3) evaluate potential impacts associated with the Stryker WWTP point source discharge, 4) develop baseline information for evaluation of agricultural land use changes (e.g., conversion to conservation tillage) currently underway in the basin, 4) determine appropriate stream use designations, and 5) conduct trend assessments (i.e., compare 1992 results to earlier data). Standardized methods were used to collect quantitative and qualitative biological, chemical and physical data from the Tiffin River basin including a 48-mile segment of the mainstem and three headwater tributaries, Mill Creek, Bean Creek and Old Bean Creek.

Aquatic Life Use Attainment:
A summary of aquatic life use attainment status for all biological sampling locations in the 1992 Tiffin River basin survey can be found in Table 1.

Tiffin River
The 1992 biological results from the 46.8 river mile mainstem study area showed 2.4 miles (5.1%) were in FULL attainment of the WWH aquatic life use designation, 44.9 miles (96.1%) were in PARTIAL attainment and 0.5 miles (1.1%) were in **NON** attainment. Locations of full and partial attainment are described below.

1) Biological assemblages in the Tiffin River were in **FULL** attainment of WWH biocriteria at one site in the upper mainstem (RM 47.6) located within the Eastern Corn Belt Plains (ECBP) ecoregion. Full attainment was attributed to relatively good water quality and habitat conditions. The ongoing trend of conversion to conservation tillage in the upper watershed during the past decade may also have had a positive influence on instream biological and water quality conditions.

2) **PARTIAL** attainment occurred at 5 mainstem locations in the Huron Erie Lake Plain (HELP) Ecoregion downstream from the village of Stryker to the mouth (RM 31.0-0.9). Primary causes of **PARTIAL** attainment were the moderate negative influences associated with past channel modifications and pervasive siltation. The presence of stable deadwood snags at these sites tended to ameliorate these influences by constricting the channel width and increasing current velocities that in turn discouraged silt deposition and substrate embeddedness. These localized areas were characterized by increased habitat heterogeneity and improved biological performance.

3) **NON** attainment occurred at one location immediately upstream from the village of Stryker (RM 35.4). This site had undergone recent channel modification associated with construction of the SR 191 bridge and was the only mainstem site that lacked significant (channel constricting) deadwood snags.

Chemical results showed water quality conditions throughout the Tiffin River were relatively good, but did reflect the widespread agricultural land use in the basin. Water quality criteria violations for dissolved oxygen, fecal coliform, nitrate and ammonia were all detected on the same date

during a period of rising flows following heavy rains. Agricultural nonpoint runoff was considered the primary source.

Biological performance in the Tiffin River, particularly among the fish community, was closely related to physical habitat conditions and the influence of agricultural land usage. *Pervasive siltation and monotonous channel development were considered the most significant negative factors currently affecting the basin.* The river was extensively modified near the turn of the century to allow agricultural drainage for cultivation. Low stream gradient coupled with the channel widening and delivery of fine silts from agricultural nonpoint sources have resulted in a heavy sediment bed load and only moderate channel recovery.

The low gradient and the highly modified character of the Tiffin River watershed coupled with the significant encroachment of adjacent land uses into the riparian zone, virtually precludes full recovery of original stream habitats. However, natural fluvial processes have resulted in **limited** recovery of stream habitats on the local (station) level. Without question, *the most influential, positive aspect of instream habitat within the Tiffin River was the presence of relatively stable dead wood snags.* Given the monotonous channel development and pervasive siltation in the mainstem, these swiftly flowing areas formed by deposits of woody debris provided critical refugia for sensitive (lithophilic and insectivorous) fishes. The vast majority of fish collected within the Tiffin Rivers during the field sampling effort were strongly associated with this habitat.

Improvements in the macroinvertebrate community was also observed in areas of swifter flow and constricted channel width. In slower currents, silt and muck tended to accumulate on the artificial substrates, resulting in lesser quaity communities and lower performance evaluations.

Following recent upgrades, the Stryker WWTP (RM 32.6) has substantially reduced loadings and was not considered a significant source of water quality impacts.

Survey results indicate Tiffin River communities are in a recovery mode and thus are quite vulnerable to any increases in either snag removal or increased siltation; the former is clearly considered the most important of the two factors. In addition, it should be recognized that the continued, wholesale channel modification of the headwater tributaries will continue to exert "negative pressure" on the mainstem and may frustrate efforts to reduce upland loadings. For these reasons, a holistic approach to watershed management that incorporates consideration of haw all these actions interact needs to be taken.

Headwater Tributaries

At tributary stations, biological communities were in **NON** attainment in Mill Creek upstream from Harrison Lake (RM 8.0/7.9), PARTIAL attainment at Mill Creek RM 2.0 and Old Bean Creek RM 1.7/1.9, and FULL attainment in Bean Creek at RM 2.3/2.2.

Old Bean Creek has exhibited little, if any, recovery from the extensive channel straightening and periodic channel maintenance that has occurred since the turn of the century. The stream was ditch-like, filled with soft silt substrates and yielded degraded biological communities in the poor to marginally good ranges. Since the prospects for future recovery of the channel are poor, the modified warmwater habitat (MWH) use designation is proposed. Bean Creek and Mill Creek have also experienced past channel modifications but have undergone varying degrees of habitat recovery.

NON attainment in Mill Creek upstream from Harrison Lake resulted from the poor condition of the fish community (IBI=19). No obvious water quality problems were detected which might account for the biological impairment observed. However, several fish kills and pollutant spills were reported in this area between 1979 and 1986. The low IBI score is indicative of a chronic problem that is likely associated with accidental and/or unreported spills in upper Mill Creek.

Historical Trends

Tiffin River

Since 1984, biological communities have shown significant improvement throughout most of the mainstem. In 1984, 29.8 river miles were not attaining WWH criteria, while 4.2 were in partial attainment and 2.3 river miles performed poorly. In contrast, the 1992 values showed 34.4 river miles partially attaining WWH criteria, 0.2 river miles not attaining and no poor performance was measured by any of the community indices. Area of Degradation Values (ADV) for the 1992 sampling effort provides a relative measure of performance, through time, of the IBI, MIwb, and ICI for the Tiffin River. A comparison of similar survey reaches in the 1984 and 1992 studies revealed ADVs for the ICI and IBI were virtually zero and the MIwb ADV was reduced about 80%. In narrative terms, biological communities have generally improved from mostly poor in 1984, to the fair to good ranges in 1992.

Improvement in the fish community appeared to result from an increase in the quality and extent of macrohabitats, due primarily to the presence of deadwood snags. It is quite possible that ongoing channel maintenance activities (public and private) over the past eight years have not aggressively cleared the stream of **all** obstructions, instead removing only significant obstructions to flow. The selective removal of deadwood snags would likely leave intact well entrenched and stable fallen timber, maintaining localized habitat heterogeneity. The primary benificial function of these snags is in restricting channel width, thus increasing flow velocity during low flow periods. This in turn discourages silt deposition and results in less substrate embeddedness than would normally occur. Also, the snags create important micro habitats where flow variations exist (e.g., underwater eddies) which offer increased niche space.

Basinwide reductions of pollutant loadings resulting from changes in land usage and point source upgrades, may have also contributed to improved biological communities in the Tiffin River. While this study could not establish specific cause/effect relationships between these occurrences and instream conditions, point source upgrades and nonpoint source reduction programs were implemented to improve water quality conditions and reduce sediment and nutrient levels in the receiving streams. The 1992 survey shows tangible instream biological improvements have coincided with these activities. Future surveys conducted as part of the Ohio EPA five year basin monitoring approach should give clearer indications of water quality trends in the basin with continued use of agricultural best management practices (BMPs) and additional recovery time.

Conclusions

Tiffin River Basin

- Fish community indices and narrative evaluations for the Tiffin River ranged between marginally good (IBI=40, MIwb=8.2) at RM 47.6 and fair (IBI=31, MIwb=7.8) at RM 26.0 and RM 14.0. Neither exceptional nor very poor performance was observed.

- The low gradient and the highly modified character of the Tiffin River watershed coupled with the significant encroachment of adjacent land uses into the riparian zone, virtually precludes full recovery of original stream habitats.

- The most influential component of macrohabitats throughout the study area was the presence of relatively stable and flow constricting deadwood snags. The swiftly flowing areas formed by the large woody debris provided critical habitat and refugia for sensitive (lithophilic and insectivorous) fish species. The vast majority of fish collected during the survey were strongly associated with this habitat.

- Predominant fish species within the Tiffin River were characterized by a marked preference for low gradient, silted, and physically disturbed waters. The abundance of these and tolerant forms reflected the pervasive modified habitat characteristics of the Tiffin River system and the intensive agricultural land use.

- The significant improvement observed within the fish community appeared to result from both an increase in the quality and extent of macrohabitats (deadwood snags) and basin wide reductions of point and nonpoint pollutant loadings.

- Water chemistry sampling throughout the basin showed all mainstem exceedences (8 of 8) and most tributary exceedences (4 of 6) occurred during the exceptionally high flow conditions encountered on July 13, 1992. Fecal coliform exceedences were found in each water body while nitrate violations and slight excursions from the daily average D.O. criterion were also detected during this sampling period. Coupled with the high levels of suspended solids following rainfall events, chemical results indicated agricultural nonpoint runoff as a primary influence on water quality in the basin.

- The Tiffin River tributaries Leatherwood Creek, Brush Creek, and Lick Creeks, though not sampled during the 1992 study, did not appear to adversely affect water quality in the Tiffin River (Figure 11).

- A sharp increase in phosphorus at RM 3.2 and zinc at RMs 3.2 and 0.9 suggested an unidentified point or nonpoint source discharge in the lower reaches of the mainstem near Brunersburg.

- Mainstem macroinvertebrate community health based on the ICI ranged from good to exceptional. Lower scores appeared primarily related to a lack of sustained, strong current over the artificial samplers and subsequent increases in silt and muck deposition. Results suggested the presence of good water quality conditions but communities were somewhat limited by the pervasive siltation encountered outside localized areas with strong flow.

- Loadings from the Stryker WWTP have been substantially reduced following upgrades in 1991. No significant chemical or biological impacts were detected downstream from the discharge. A minor exceedance for ammonia detected 6.5 miles downstream under high flow conditions may have resulted from the WWTP, but could not be specifically linked to the discharge.

- Fish tissue analysis in the Tiffin River revealed detectable quantities of mercury, some pesticides and the PCB congener, Alochlor-1260 (PCB-1260). However, *all concentrations were well below FDA action limits.*

- Concentrations of sediment metals and organics were not a significant concern in the Tiffin River. Chromium was the only metal found above the "elevated" range and organics were mostly below detection limits and therefore were non-elevated. The banned pesticide dieldrin was ranked as "slightly elevated" upstream and downstream from the Village of Stryker. The common plasticizer, Di-N-Butyl-Phthalate, was detected in the impounded section at RM 0.9. This latter finding along with the elevated zinc and phosphorus in the water column possibly suggests an unidentified source.

Recommendations

Status of Aquatic Life Uses

- Several streams evaluated during this study were originally designated for aquatic life uses in the 1978 Ohio WQS. The techniques used then did not include standardized approaches to the collection of instream biological data or numerical biological criteria. Therefore, because this study represents a first use of this type of biological data to evaluate and establish aquatic life use designations in several stream segments in the study area, several revisions are recommended. While some changes may appear to constitute "downgrades" (i.e., EWH to WWH, WWH to MWH, etc.) or "upgrades" (i.e., LWH to WWH, WWH to EWH, etc.), any changes should not be construed as such because this constitutes the first use of an objective and robust use evaluation system and database. The Ohio EPA is under obligation by a 1981 public notice to review and evaluate all aquatic life use designations outside the WWH use before basing any permitting actions on the existing, unverified use designations. Thus, some of the following aquatic life use recommendations constitute a fulfillment of that obligation.

- The following Tiffin River basin streams were surveyed in 1992 and are recommended to retain their current WWH aquatic life use designations. The designations apply to the entire length of the streams unless otherwise noted.

  1) Tiffin River Mainstem
  2) Bean Creek
  3) Mill Creek

- Changes in use designation status are recommended for the following tributary:

  1) <u>Old Bean Creek (WWH Existing / MWH Recommended)</u>
  Old Bean Creek has exhibited little, if any, recovery from the extensive channel straightening and periodic channel maintenance that has occurred since the turn of the century. In 1992, the stream was ditch-like, filled with soft silt substrates and yielded degraded biological communities in the poor to marginally good ranges. A habitat evaluation at RM 1.7 revealed a QHEI of 29.5 and a strong predominance of high influence modified habitat attributes - this condition is representative of the entire stream. Given the very low stream gradient and on-going channel maintenance, the potential for physical recovery of the channel is low. Channel maintenance activities are sanctioned uner the Ohio Drainage Law (ORC 6131). Therefore, the Modified Warmwater Habitat use designation is recommended.

Status of Non-Aquatic Life Uses

- No changes are recommended to the existing non-aquatic life use designations currently listed in the Ohio WQS. These uses include agricultural and industrial water supply, primary and secondary contact recreation, public water supply, and State Resource Water (SRW). For a complete description of each designation, refer to Chapter 3745-1-11 of the Ohio WQS.

Other Recommendations

- The 1992 survey results illustrate the importance of flow constricting deadwood snags to improved biological performance in the mainstem. In the future, plans for snag clearing and other channel modifications should give careful consideration to the negative impacts associated with removal of these structures. By using a selective approach, large accumulations that are significant obstructions to flow or which significantly threaten property could continue to be removed, while leaving intact the well entrenched and stable fallen timber that maintains habitat diversity and improves biological conditions. Removal of these structures would certainly result in a reduction of biological performance and potentially would violate the biocriteria in the WQS.

- Agricultural sediment and nutrient loads should be reduced through continued implementation of conservation tillage, filter strips, and other agricultural best management practices. However, the overall success of these reductions is also contingent on meeting the previous recommendation.

Future Monitoring Needs

- Efforts should continue to evaluate the effectiveness of the nonpoint source pollution abatement projects being conducted within the Tiffin River watershed. This includes not only the usual tracking of upland BMP implementation, but careful monitoring of log jam removal, riparian and instream channel modification. Given the significant increases in conservation tillage, revisiting the basin during the 1997 five-year monitoring cycle is strongly urged to continue tracking the actual impact of these changes.

- Attempts should be made to evaluate potential impacts from nonpoint source pollution in previously unmonitored stream segments in the Tiffin River watershed.

- Additional investigation in the upper Mill Creek basin is needed to more accurately determine the cause(s) of **NON** attainment (fish community in the poor range; IBI=19). Since a series of pollutant spills and fish kills were reported from the area since the mid 1980s, more recent, unreported spill(s) were considered as possible causes of the impairment observed in 1992.

- Additional investigation of the cause of water column and sediment contamination in the lower Tiffin River mainstem should be conducted.

- Future investigative monitoring of sediment chemistry should be conducted in the Tiffin River watershed to determine if pretreatment programs were effective in reducing metals loadings and/or locate other potential sources.

Table 1. Aquatic life use attainment status for the designated Warmwater Habitat (WWH) aquatic life use designation in the Tiffin River and tributaries based on data collected from June to October, 1992. Attainment status is based on biocriteria for the Eastern Corn Belt Plains and Huron-Erie Lake Plain ecoregions of Ohio (OAC 3745-1-07, Table 7-17).

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status	Comment
Tiffin River						
Eastern Corn Belt Plain -WWH Use Designation						
47.6/47.6	40ns	8.2ns	50	49.5	FULL	Dst. Headwater Tribs.
Huron-Erie Lake Plain - WWH Use Designation						
35.4/35.4	29*	6.3*	34	36.0	NON	Ust. Stryker
31.0/31.0	37	7.7*	42	53.0	PARTIAL	Dst Stryker WWTP
26.0/26.2	31ns	7.8*	54	47.5	PARTIAL	
14.1/14.2	31ns	7.8*	MG	43.5	PARTIAL	
6.9/7.1	36	8.0*	54	45.0	PARTIAL	
1.1/0.9	36	7.9*	34	43.0	PARTIAL	Impounded
Mill Creek						
Eastern Corn Belt Plain - WWH Use Designation						
8.0/7.9	19*	6.4*	G	58.5	NON	Ust. Harrison Lake
2.0/2.0	30*	7.2*	MG	62.5	PARTIAL	Dst. Harrison Lake
Bean Creek						
Eastern Corn Belt Plain - WWH Use Designation						
2.3/2.2	41	8.0ns	G	50.0	FULL	
Old Bean Creek						
Eastern Corn Belt Plain - WWH Use Designation (Existing) / MWH (Recommended)						
1.7/1.9	33*	8.0ns	P*	29.5	NON/NON	

Ecoregion Biocriteria: Eastern Corn Belt Plains (ECBP)

INDEX - Site Type	WWH	EWH	MWH[c]
IBI - Wading	40	50	24
IBI - Boat	42	48	24
Mod. Iwb - Wading	8.3	9.4	6.2
Mod. Iwb - Boat	8.5	9.6	5.8
ICI	36	46	22

Ecoregion Biocriteria: Huron-Erie Lake Plain (HELP)

INDEX - Site Type	WWH	EWH	MWH
IBI - Boat	34	48	24
Mod. Iwb - Boat	8.6	9.6	5.8
ICI	34	46	22

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - nonsignificant departure from ecoregional biocriteria (4 IBI or ICI units; 0.5 Mod. Iwb units).
a - Narrative evaluation used in lieu of ICI (G=Good, MG=Marginally Good, P=Poor).
b - Qualitative Habitat Evaluation Index (QHEI) values based on the new version (Rankin 1989).
c - Modified Warmwater Habitat for channel modified areas.

Study Area

The Tiffin River and its tributaries drain 553.5 square miles in northwest Ohio and 251 square miles in southeast Michigan and includes parts of Defiance, Williams, and Fulton counties in Ohio as well as parts of Hillsdale and Lenawee counties in Michigan (ODNR 1960). The area is approximately 40 miles west of the Toledo metropolitan area. The Tiffin River is formed by the confluence of two tributaries, Bean Creek and Mill Creek, which join together in Fulton County, 51 miles upstream from the Maumee River. The river and its tributaries flow in a southerly direction through glaciated topography to drain into the Maumee River just upstream from the city of Defiance. Major tributaries of the Tiffin River are Lick Creek, Brush Creek, Beaver Creek, Mill Creek, and Bean Creek. The communities of Bryan, Stryker, West Unity and Archbold are the major population centers. The Tiffin River study area (Figure 1) consists of the entire length of the Tiffin River as well as an 8 mile segment of Mill Creek and 2 mile segments of both Bean Creek and Old Bean Creek. Table 2 presents the general characteristics of the streams in the study area.

The Tiffin River basin is located within the Huron/Erie Lake Plain (HELP) and the Eastern Corn Belt Plains (ECBP) ecoregions. Approximately 50% of the Tiffin River watershed lies within the ECBP ecoregion, including most of the headwaters and upper mainstem. The ECBP consists of rolling glacial end moraines deposited on Devonian limestone. Land use in the region consists of extensive cropland (>75%) agriculture with local relief generally less than 50 feet. Soils are derived from glacial till materials and poor soil drainage has prompted extensive stream channelization to assist artificial drainage from crop fields.

About two thirds of the lower mainstem watershed is located within the HELP ecoregion. The HELP is characterized by a broad, almost level, lake plain crossed by low moraines and beach ridges. In Ohio, this area is largely the remnant of the Black Swamp, a deforested and extensively drained wetland. Most of the region was channelized and drained for cropland by the turn of the 20th century. Stream gradients are very low, with most less than 1-2 ft/mile. Local relief is generally only a few feet and the soils are poorly to very poorly drained. Corn and soybean farming is the predominant land use and requires an extensive drainage ditch system to make row crop farming possible. In Ohio, the HELP has the most widespread and severe agricultural impacts of any of the five Ohio ecoregions. This is primarily related to channelization, soft silt and muck substrates, a lack of woody riparian vegetation, and low stream gradients, all of which can often preclude recovery of original stream habitats.

All streams in the watershed currently have Warmwater Habitat (WWH) aquatic life use designations. The portion of the Tiffin River bordering the Goll Woods Preserve in Fulton County has been designated a State Resource Water (SRW) in the Ohio Water Quality Standards (Ohio EPA 1988).

The Tiffin River flows through an area used extensively for agricultural crop production. Land use in the watershed is approximately 85% cropland, 9% woodland, 1% pasture, and 5% other land uses (SCS 1990). Corn and soybeans are the principal crops; other feed grains and hay for livestock are also grown. Fulton County is consistently among the top Ohio counties in corn and hog production (ODA 1992). Poor soil drainage has led to extensive stream channelization to assist artificial field drainage systems. Agriculture and channelization are the predominant types of nonpoint source (NPS) pollution in the watershed (Ohio EPA, 1990b). The identified pollution sources in the study area are presented in Table 2.

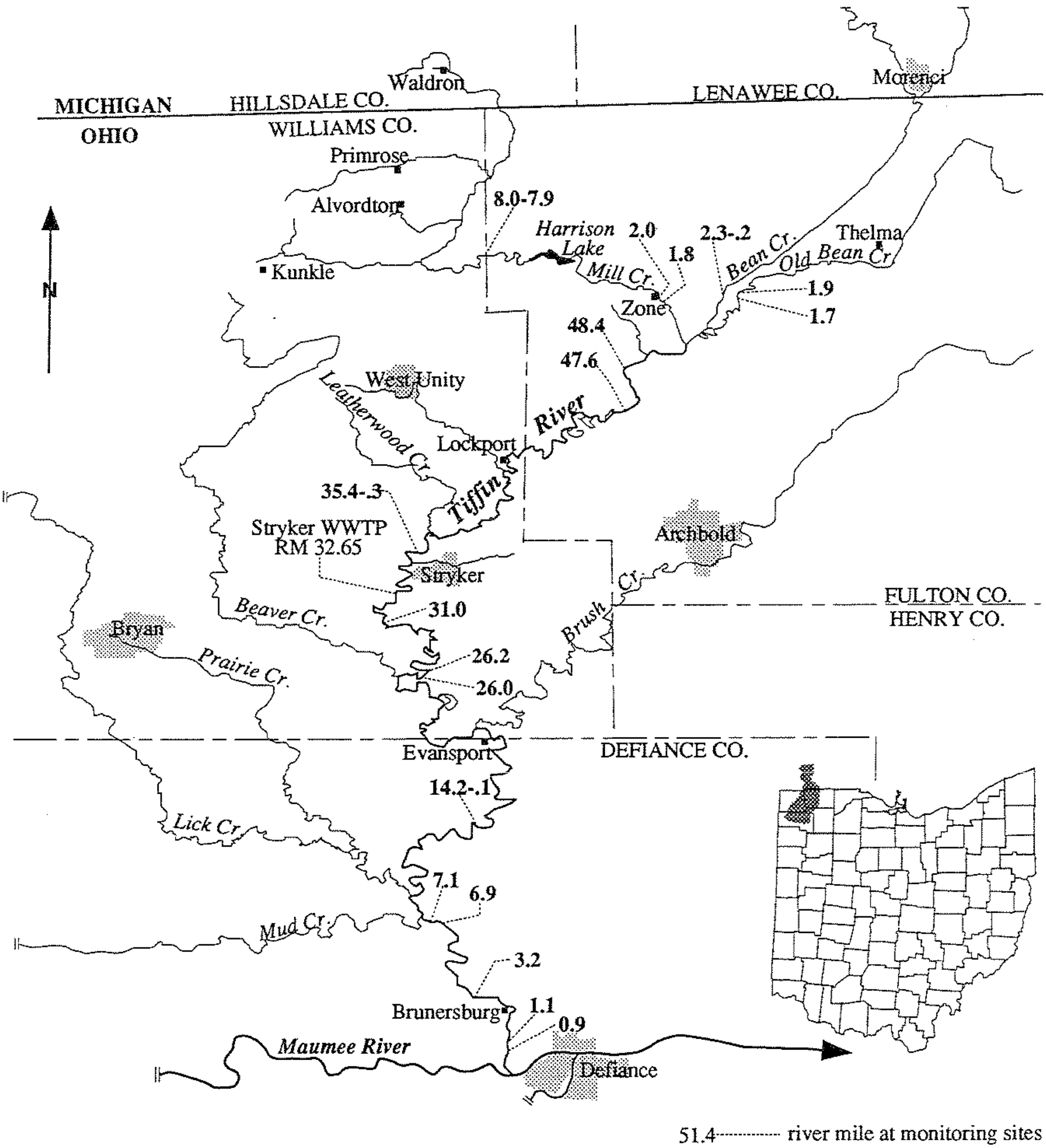


Figure 1. The Tiffin River study area showing principal streams and tributaries, population centers, pollution sources and water quality monitoring sites, 1992.

Agricultural land use practices in the watershed are undergoing significant changes as a result of a number of ongoing and completed projects designed to assist farmers in implementing agricultural best management practices such as conservation tillage, filter strips, and nutrient management (Figure 2). When implemented, these best management practices are expected to reduce sediment and nutrient loads to streams within the watershed. The projects expected to improve water quality in the Tiffin River watershed include:

1) Upper Tiffin Watershed Project, a hydrologic unit area project being coordinated by the Soil Conservation Service to promote the use of agricultural BMPs in the watershed;

2) Harrison Lake Project, USEPA/Section 319 funding is being used to promote agricultural BMPs that will reduce the sediment and nutrient load to the lake;

3) Upper Lost Creek Project, USEPA/Section 319 funding is being used to promote agricultural BMPs;

4) Maumee River Equipment Buydown Project, USEPA/Section 319 funding is being used to assist farmers with the purchase of conservation tillage equipment;

5) Manure and Nutrient Management Program, a State funded program being conducted in Fulton County to implement various BMPs related to livestock waste disposal;

6) Conservation Reserve Program, U.S. Department of Agriculture funding is being used to take highly erodible and riparian cropland out of production for a 10 year period.

The water quality information collected in the Tiffin River watershed in 1992 and beyond will provide baseline data which will assist in evaluating the effectiveness of these projects.

Although statistics measuring conservation tillage by watershed boundary are generally unavailable, it is estimated that conservation tillage is now being used on over fifty percent of all row crops in the Tiffin River watershed (Williams Co. SWCD 1993). Within the counties of Defiance, Fulton and Williams counties, use of conservation tillage has increased dramatically during the past decade. By contrast, in 1981, approximately 3 percent of corn and soybean acreage in these was produced using conservation tillage (Table 3). Most of the remaining crop land was managed using tillage systems which provided inadequate protection from soil erosion. By 1992, over 50 percent of the corn and soybeans were being produced using conservation tillage practices. Thousands of additional acres of cropland now have improved and/or adequate protection from soil erosion.

In addition to the increase in conservation tillage, thousands of acres of highly erodible and riparian cropland have been taken out of crop production, since 1988, through enrollment in the Conservation Reserve Program (CRP). Williams County's CRP enrollment is the highest in Ohio with 34,784 acres; Defiance County has 16,656 CRP acres and Fulton County has 4,089 CRP acres (SCS 1993). The net result of these recent land use changes is a significant reduction of the sediment and phosphorus load, which given time, is expected to improve water quality in the Tiffin River.

Table 2. Stream characteristics and significant identified pollution sources in the Tiffin River study area, 1992 (from ODNR, 1960 and Ohio EPA, 1990, 1992).

Stream Name	Length (Miles)	Average Fall (Feet/Mile)	Drainage Area (Square Miles)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Tiffin River	50.8	1.2	804.5	Agriculture Channelization	Stryker WWTP
Mill Creek	20.0	8.4	40.3	Agriculture Channelization Silviculture	Harrison Lake State Park WWTP
Bean Creek	39.8	3.0	260.0	Agriculture Channelization Silviculture	
Old Bean Creek	8.4	1.2	33.6	Agriculture Silviculture Channelization	

Table 3. Corn and soybean acreage and percentage produced using conservation tillage (greater than 30% residue cover after planting) in three Ohio counties encompassing much of the Tiffin River watershed.

County	Year	Corn Acres	Corn Percent	Soybeans Acres	Soybeans Percent
Defiance	81*	500	1.3	300	0.3
	86	3326	10.0	4234	6.0
	92	25846	60.2	52944	55.0
Fulton	81*	950	1.0	750	1.0
	86	21170	24.0	6774	10.0
	92	45400	51.5	49486	54.0
Williams	81*	1500	3.0	500	1.0
	86	13374	27.0	10774	16.0
	92	22532	43.2	38344	54.2

* The 1981 data is only roughly comparable to the 1986 and 1992 data due to a radical change in the data collection technique implemented in 1986. To compensate for the change in collection technique, the amounts shown for 1981 represent only those acres reported for No-Till systems.

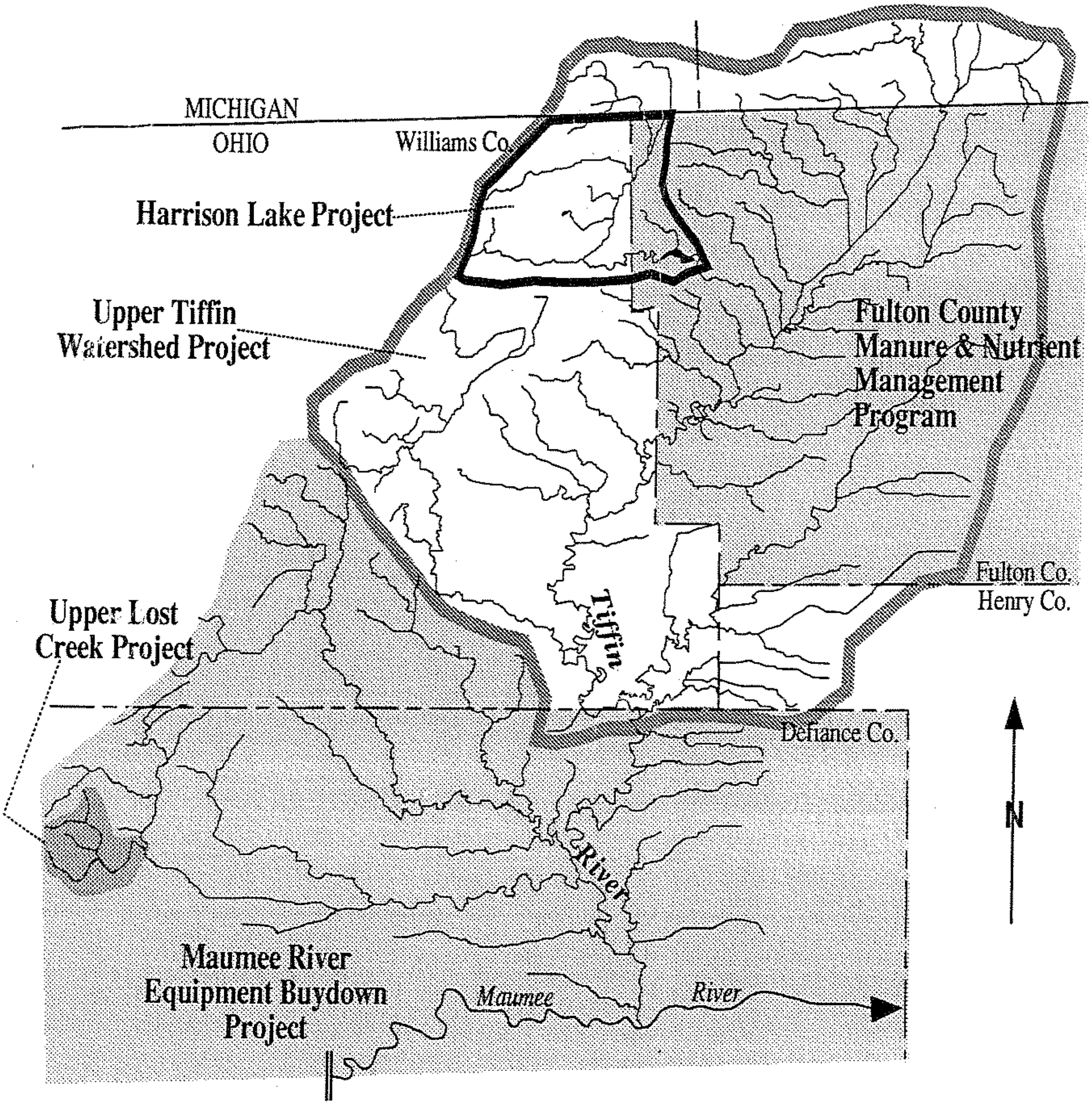


Figure 2. The Tiffin River watershed showing locations of nonpoint source pollution abatement project areas, 1992.

Methods

All chemical, physical, and biological field, laboratory, data processing, and data analysis methods and procedures follow those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes II-III (Ohio Environmental Protection Agency 1987, 1989b, 1989c), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989) for aquatic habitat assessment.

Attainment/non-attainment of aquatic life uses is determined by using biological criteria codified in Ohio Administrative Code (OAC) 3745-1-07, Table 7-17. The biological community performance measures that are used include the Index of Biotic Integrity (IBI) and the Modified Index of Well-being (MIwb), both of which are based on fish community characteristics, and the Invertebrate Community Index (ICI) which is based on macroinvertebrate community characteristics. IBI and ICI are multi-metric indices patterned after an original IBI described by Karr (1981) and Fausch et al. (1984). The MIwb is a measure of fish community abundance and diversity using numbers and weights information; it is a modification of the original Index of Well-Being applied to fish community information from the Wabash River (Gammon 1976, Gammon et al. 1981).

Performance expectations for the basic aquatic life uses (Warmwater Habitat [WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes *et al.* 1986; Omernik 1988). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Attainment of an aquatic life use is **FULL** if all three indices (or those available) meet the applicable criteria, **PARTIAL** if at least one index does not attain and performance does not fall below the fair category, and **NON** if all indices either fail to attain or any index shows poor or very poor performance.

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989). Various attributes of the available habitat are scored based on their overall importance to the establishment of viable, diverse aquatic faunas. Evaluations of type and quality of substrate, amount of instream cover, channel morphology, extent of riparian canopy, pool and riffle development and quality, and stream gradient are among the metrics used to determine the QHEI score. Scores generally range from 20 to 100. The QHEI is used to evaluate the characteristics of a stream segment, not just the characteristics of a single sampling site. As such, individual sites may have much poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have shown that values higher than 60 are generally conducive to the establishment of warmwater faunas while those scores over 75-80 often typify habitat conditions that could support exceptional faunas.

During this survey, macroinvertebrate communities from the Tiffin River were sampled using modified Hester/Dendy multiple-plate artificial substrate samplers supplemented with a qualitative assessment of macroinvertebrates (taxa list) from the available natural substrates. Qualitative assessments only were conducted at tributary sites in Mill Creek, Bean Creek and Old Bean Creek and one location in the Tiffin River (RM 14.2) where the artificial substrate samplers were lost.

Fish were sampled 2-3 times using pulsed DC electrofishing gear using either the wading method (150 meter zones) or boat method (500 meter zones). All locations were electrofished using the boat method except Mill Creek (wading method). All chemical/physical and biological sampling locations are listed in Table 4.

An Area of Degradation Value (ADV; Rankin and Yoder 1991) was calculated for the study area based on the longitudinal performance of the biological communities. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, and ICI) departs from the stream criterion or the upstream level of performance (Figure 3). The magnitude of impact refers to the vertical departure of each index below the criterion. The total ADV is the area beneath the ecoregional criterion when the results for each index are plotted against river mile. This is also expressed as ADV/mile to normalize comparisons between segments and other areas.

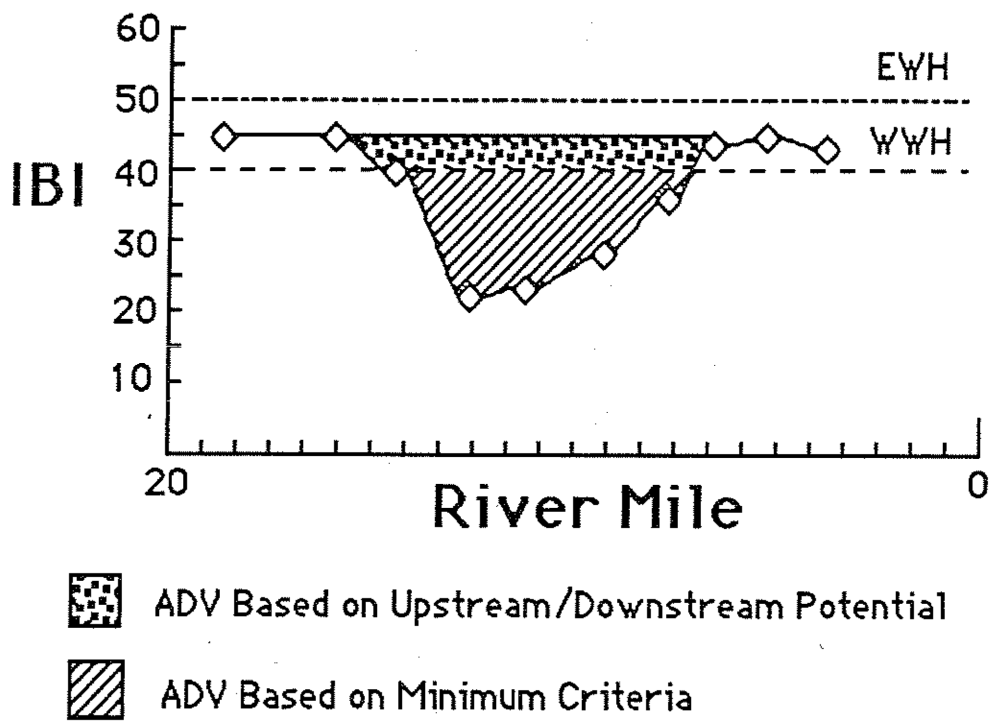


Figure 3 . Graphic illustration of the calculation of Area of Degradation Values (ADV) based on upstream potential and the ecoregion Warmwater Habitat use or minimum criterion (WWH). Criteria for Exceptional Warmwater Habitat use (EWH) is provided for reference.

Table 4. Sampling locations (water chemistry - C, sediment chemistry - S, benthos - B, fish - F, fish tisue - FT) in the Tiffin River study area, 1992.

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 min. Quad. Map
Tiffin River				
48.4	C,FT	41 34 53 / 84 20 03	Alt. US 20	Archbold
47.6	F,B	41 34 22 / 84 20 14	Burlington Rd.	Archbold
35.4	F,B	41 30 35 / 84 25 37	SR 191	West Unity
35.3	C,S	41 42 05 / 84 25 43	SR 191	West Unity
31.0	C,F,B	41 28 43 / 84 26 28	SR 34/2	Evansport
26.2	C,B,S	41 27 23 / 84 26 30	Oak Grove Church Rd.	Evansport
26.0	F	41 27 19 / 84 25 25	Oak Grove Church Rd.	Evansport
14.2	B	41 23 18 / 84 23 45	Stever Rd	Evansport
14.1	F,FT	41 23 17 / 84 23 46	Stever Rd	Evansport
7.1	C,B,S	41 20 47 / 84 25 08	Evansport Rd.	Defiance West
6.9	F	41 20 47 / 84 24 54	Evansport Rd.	Defiance West
3.2	C	41 18 47 / 84 23 56	Stever Road	Defiance West
1.1	F	41 17 37 / 84 23 14	Dey Rd	Defiance West
0.9	C,B,S	41 17 25 / 84 23 08	Dey Rd	Defiance West
Mill Creek				
8.0	F	41 38 31 / 84 24 00	County Line Rd.	Alvordton
7.9	C,B	41 38 30 / 84 24 55	County Line Rd.	Alvordton
2.0	F,B	41 37 30 / 84 19 38	Old Angola Rd.	Archbold
1.8	C	41 37 22 / 84 19 25	Old Angola Rd.	Archbold
Bean Creek				
2.3	F	41 37 30 / 84 17 45	Old Angola Rd.	Archbold
2.2	C,B	41 37 13 / 84 17 46	Old Angola Rd.	Archbold
Old Bean Creek				
1.9	C,B	41 37 24 / 84 17 25	Old Angola Rd.	Archbold
1.7	F	41 37 18 / 84 17 24	Old Angola Rd.	Archbold

Results and Discussion

Pollutant Loadings: 1982- 1992

Mill Creek - Harrison Lake State Park WWTP:

- The Ohio Department of Natural Resources operates an extended aeration wastewater treatment plant at Harrison Lake State Park (Ohio EPA permit # 2PP00001) which treats an average of 0.040 MGD. The plant was originally constructed in 1971 and was upgraded by the addition of sand filters in 1982. Effluent is discharged to Mill Creek downstream from the Harrison Lake dam spillway at RM 5.0. A package sewage treatment plant serves Camp Palmer (4-H camp) on the northwest end of Harrison Lake and the potential for high fecal coliform levels entering the lake exists (A. Rupp, Ohio EPA, personal communication, 1993).

- A review of available NPDES compliance records for Harrison Lake State Park WWTP showed occasional violations of permit limits during the period 1987-1992. There were 11 violations during this period, but there was no clear pattern of noncompliance with any specific parameter.

Tiffin River - Village of Stryker WWTP:

- Stryker operates an extended aeration wastewater treatment system consisting of two aerated stabilization ponds in series, a polishing lagoon, rock filter and final aeration basin (Ohio EPA permit 2PB00009) with a design capacity of 0.350 MGD. The plant was originally constructed in 1965 and was last upgraded in 1991. Effluent is discharged to the Tiffin River at RM 32.6. The collection system has 100% separate sanitary sewers and has no overflows or bypasses. Flow monitoring was not conducted prior to 1982 due to inoperative monitoring equipment. Discharges fluctuated between 1982 and the 1992 survey year and are characteristic of lagoon systems responding to rainfall events (Figure 4). Total suspended solids (TSS), 5-day biochemical oxygen demand (BOD_5), ammonia, and total phosphorus concentrations declined significantly and reflect reduced loadings after the 1991 plant upgrades (Figure 4).

- A review of the NPDES compliance records for the Village of Stryker WWTP from September 1983 through December 1990 showed frequent violations of permit limits for TSS and BOD_5. TSS and/or BOD_5 violations occurred in at least 71 months during this 88 month period. The plant upgrade in 1991 appears to have corrected this situation. TSS and BOD_5 limits were violated only once in 1991 and no violations occurred in 1992.

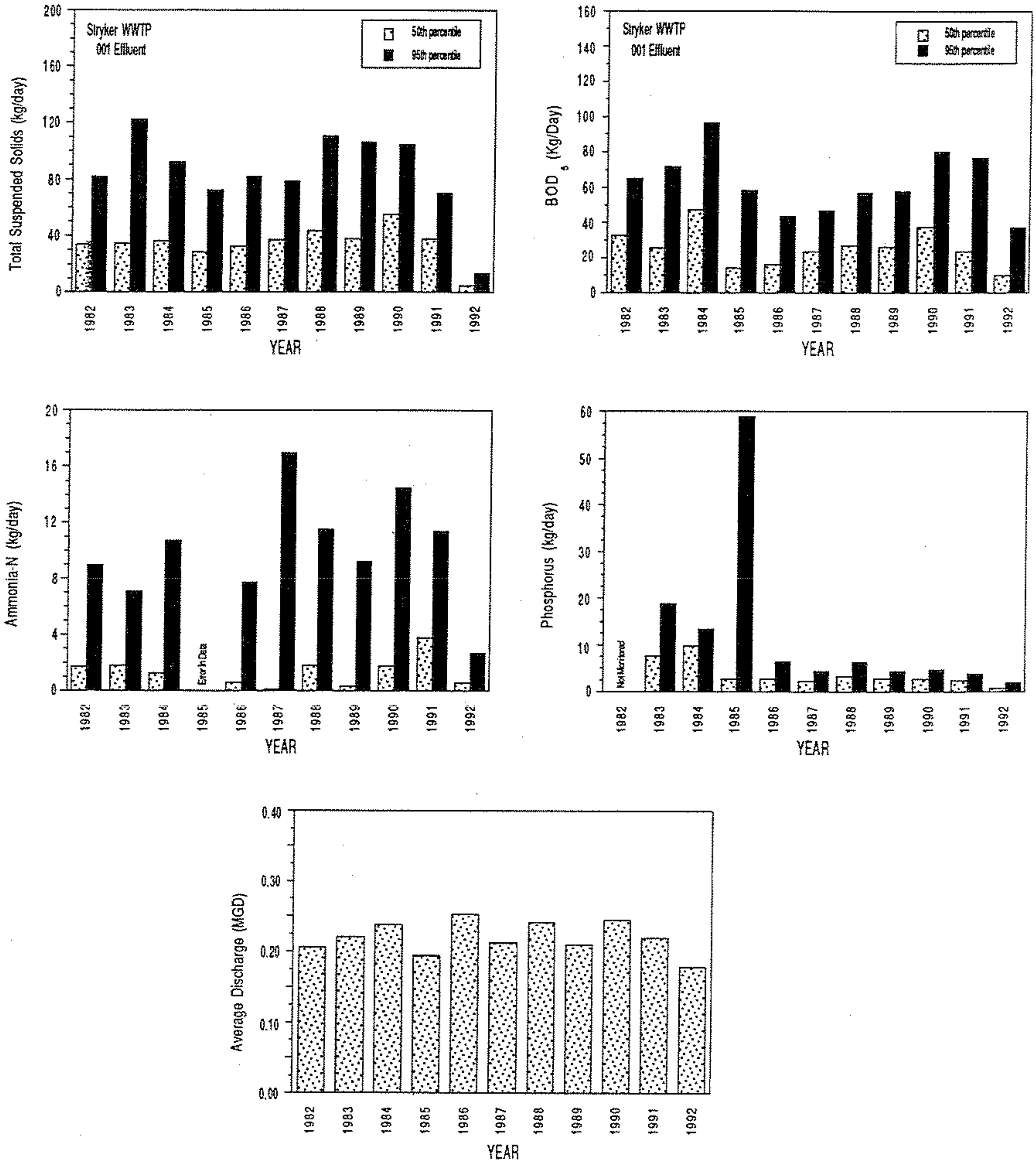


Figure 4. Annual loadings (kg/day) of total suspended solids (TSS), 5-day biochemical oxygen demand (BOD_5), ammonia, phosphorus, and mean annual discharge flow (MGD) at the Stryker WWTP, 1982-92. The WWTP was upgraded in 1991.

Pollutant Spills

Lists of spills and wild animal kills are also indications of possible impacts due to pollutant loadings (Appendix Table 1). A review was conducted of discharges and kills in the Tiffin River basin (in Fulton, Williams and Defiance Counties, Ohio) as reported by Ohio EPA's Division of Emergency and Remedial Response and Ohio Department of Natural Resources (ODNR) Division of Wildlife Pollution Investigative Reports. Results from 1978 through 1992 show:

- Ohio EPA and Ohio DNR list a total of 77 pollutant discharges from spills and permit violations in the Tiffin River basin since 1978. For 33 of the incidents with amounts reported, a total of 478,076 gallons of pollutants were released. Twenty four of the 77 spills were petroleum products followed by sewage (14), fertilizer products (14), industrial chemicals (6), herbicides and pesticides (4), and acids (3). Most petroleum discharges were associated with small industries, businesses, and trucking companies while the majority of sewage discharges were related to municipal WWTP bypasses or permit violations. Spills of fertilizers, pesticides and farm chemicals were primarily associated with agricultural operations and the farm services industry. The two largest (quantified) spills in the basin occurred in 1991 when 250,000 gallons of raw sewage from the Morenci WWTP were discharged to upper Bean Creek and 160,000 gallons of corn syrup (from Consolidated Rail Corp.) were spilled into a ditch near the village of Stryker.

- During the same period pollution investigation reports list eleven incidents where a total of 76,635 fish were killed within the basin. All incidents appeared to be limited to tributaries with no reports for the Tiffin River mainstem. Most of the kills resulted from farm chemical spills associated with agriculture.

- Between 1979 and 1986, seven pollution spills occurred in the Mill Creek watershed from the headwaters to Harrison Lake. Fish kills were associated with four of the spills, including an incident in 1979 when 72,558 fish died following a 5,000 gallon spill of fertilizer in Alvordton. Although no spills have been reported in the area since 1986, observations of degraded fish communities in 1992 suggests the existence of recent or continued problems with pollutant discharges in the form of periodic spills in upper Mill Creek.

Chemical Water Quality

General

- Eleven sites in the Tiffin River study area were selected for chemical analysis of surface water. Seven of these sites were located on the Tiffin River mainstem, two on Mill Creek and one each on Bean Creek and Old Bean Creek. Temperature, dissolved oxygen (D.O.), and pH were measured in the field at the time of sample collection. A summary of these results can be found in Appendix Table 2.

- Exceedences of Ohio Water Quality Standards (OAC 3745-1) were determined for those parameters which have established numerical criteria. A summary of all exceedences can be found in Table 5. All stream segments in the study area are currently assigned the Warmwater Habitat use and Primary Contact Recreation use. One segment of the Tiffin River adjacent to Goll Woods in Fulton Co. is also designated as a State Resource Water.

Table 5. Exceedences of Ohio EPA Warmwater Habitat criteria (OAC 3745-1) for chemical/physical parameters measured in grab samples taken from the Tiffin River survey area during 1992 (units are colonies/100ml for fecal coliform and mg/L for all other parameters).

Stream	River Mile	Parameter (value)
Mill Creek		
	7.9	Fecal Coliform (>10000 ◊◊)
Old Bean Creek		
	1.8	Fecal Coliform (3000 ◊); D.O. (4.9 ‡); NO_3-N (13.38 †, 10.42 †)
Bean Creek		
	2.2	Fecal Coliform (>10000 ◊◊); NO_3-N (11.31 †)
Tiffin River		
	48.4	Fecal Coliform (>10,000 ◊◊)
	35.3	Fecal Coliform (4,000 ◊)
	31.0	D.O. (4.9 ‡)
	26.2	NO_3-N (19.35 †); NH_3-N(.62 *)
	7.1	Fecal Coliform (2800 ◊)
	3.2	D.O. (4.8 ‡)
		57 of 66 iron samples (86.4%) exceeded 1.0 mg/l in the Tiffin River survey area.

* indicates an exceedence of numerical criteria for prevention of chronic toxicity (CAC).
‡ violation of the average dissolved oxygen (D.O.) criterion.
◊ exceedence of the Primary Contact Recreation criterion.
◊◊ exceedence of the Secondary Contact Recreation criterion.
† violation of the human health criterion for public water supplies.

Tiffin River

- The flow hydrograph depicting daily discharge in the Tiffin River at Stryker from May to October indicates peak flows in 1992 occurred during the months of July and September and were well above normal summer flow during much of the July through September sampling period (Figure 5). The highest daily mean flow for the 1992 water year was recorded on July 27 (1480 cfs). During an earlier survey in 1984, highest flows were found during the May-June period but remained above the 80% duration value throughout the summer-fall sampling period (Figure 5).

- The flow hydrograph depicting daily discharge in the Tiffin River at Stryker indicated peak flows occurred during the May-June period in 1984 and during the July-September period in 1992 (Figure 5).

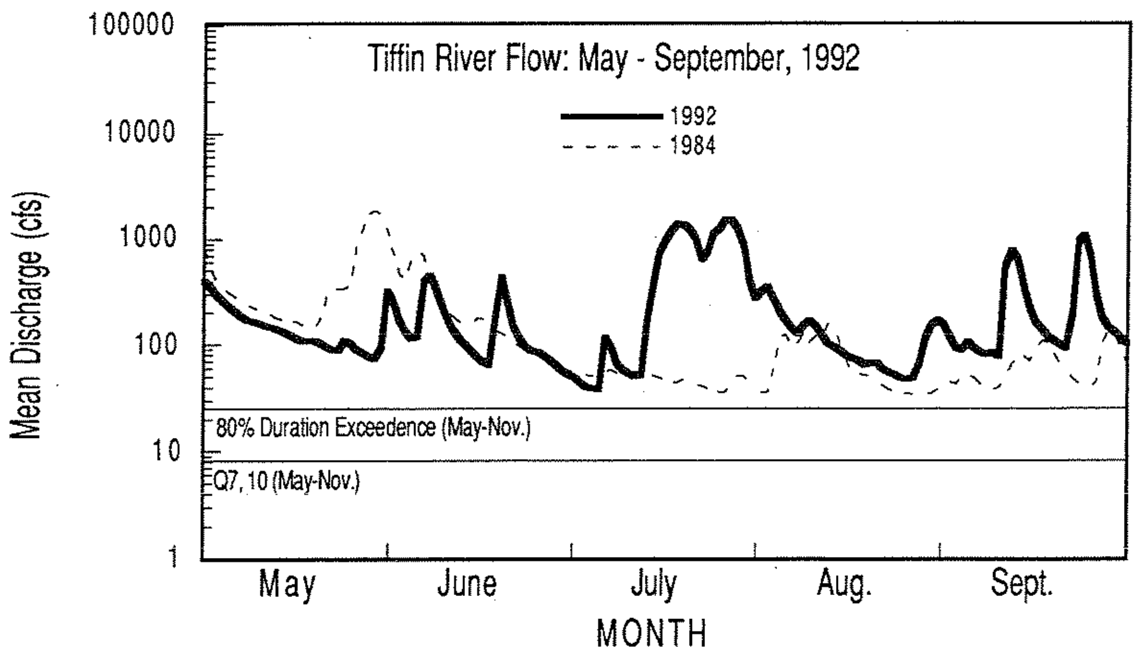


Figure 5. Flow hydrograph for the Tiffin River at Stryker, Ohio (RM 34.7), May through September, 1992 and 1984. May through November low-flow conditions ($Q_{7,10}$ [8.1cfs] to 80% duration flow [25 cfs] for the period of record [1921-1978] are indicated on the flow hydrograph.

- Bean Creek, Old Bean Creek, and Mill Creek combine to form the headwaters of the Tiffin River. The Tiffin River drains 804.5 square miles, including 251.0 sq. mi. in Michigan (primarily in the Bean Creek drainage). The predominant land use is agricultural. The average stream gradient is 1.2 feet per mile. The Tiffin River is tributary to the Maumee River at RM 65.7 just upstream of Defiance.

- The Tiffin River receives an NPDES permitted discharge from the Village of Stryker WWTP at RM 32.65. The Stryker WWTP was a consistent source of high total suspended solids (TSS) and BOD_5 until the plant was upgraded in 1991.

- Surface water samples were collected from seven sites on the Tiffin River mainstem. The seven exceedences of Ohio Water Quality Standards (WQS) recorded occurred on July 13, 1992, as the river was rising following heavy rains the previous day. These included violations of fecal coliform bacteria (RMs 48.4, 35.3 and 7.1), nitrate (RM 26.2), dissolved oxygen (RM 31.0 and 3.2) and ammonia at RM 26.2 (Table 5). Initial runoff (i.e., "first flush") samples often contain high concentrations of pollutants associated with diffuse runoff. Elevated concentrations on July 13 were likely the result of nonpoint pollution sources related to the pervasive agricultural land use in the basin.

- The ammonia exceedence at RM 26.2 was detected approximately 6.5 miles downstream from the Stryker WWTP. This exceedence was not particularly serious and could have been caused by any number of sources and/or relatively high ph and temperature. Except for this value, mean ammonia concentrations for remaining 1992 sampling dates downstream from the WWTP underwent minimal change (Figure 6). These results and the relatively small size of the plant (0.35 MGD) suggested the WWTP was not a significant source of ammonia. Above average levels of BOD, TSS, phosphorus and nitrate were also detected on July 13 at most sampling stations.

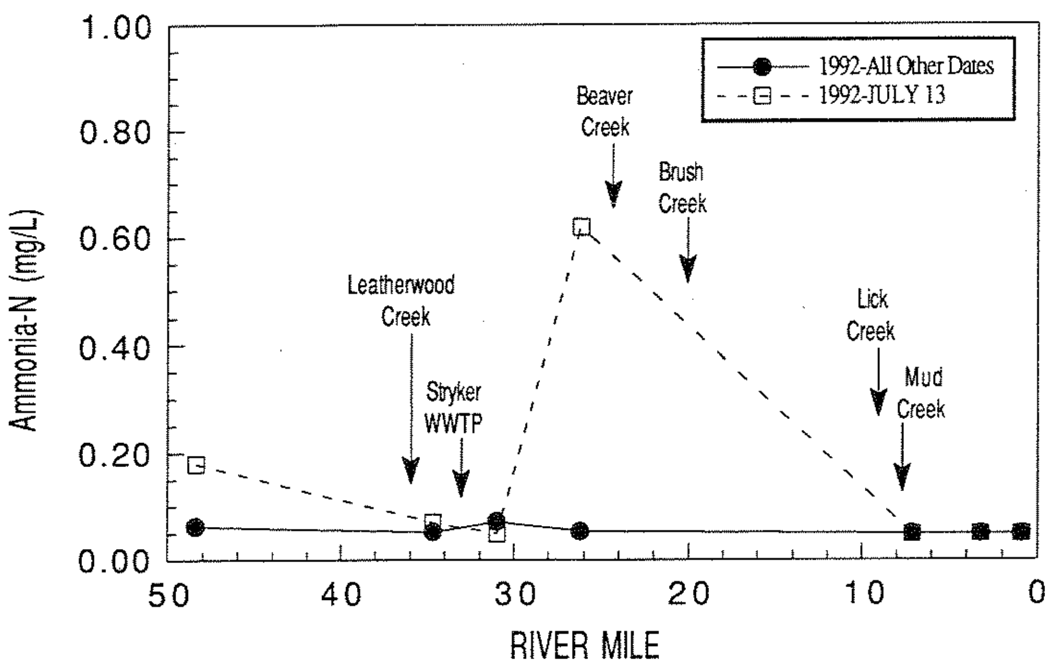


Figure 6. Longitudinal trend of ammonia concentrations in the Tiffin River on July 13, 1992 and mean concentrations during all other 1992 sampling dates.

- Total phosphorus had relatively stable mean concentrations along the Tiffin River, except for RM 3.2 where an increase in mean total phosphorus suggested a possible unidentified point or nonpoint source input (Figure 7).

- Mean total suspended solids (TSS) results suggested that agricultural runoff was the major source of this pollutant in the Tiffin River upstream from RM 35.3 (Figure 7). Stream hydrology between RM 31.0 and RM 7.1 and peak flow periods during the survey year contributed to the gradual increase in TSS. The significant decline in TSS downstream from RM 7.1 is most likely a result of impoundment and low stream gradient as the mainstem enters old lake bed topography.

Old Bean Creek

- Old Bean Creek drains 33.6 square miles of predominately agricultural land. The average stream gradient is 1.2 feet per mile. Old Bean Creek receives no point source discharges from National Pollutant Discharge Elimination System (NPDES) permitted entities in Ohio.

- Violations of Ohio WQS in Old Bean Creek at RM 1.8 were limited to a daily average criterion for D.O. and the exceedence of primary contact recreation criterion for fecal coliform, both on July 13, 1992 (Table 5). This sample was collected during high flow conditions following a storm event (Figure 5), so it is likely the high fecal coliform count was due to nonpoint source runoff and interference from soil bacteria. Although Old Bean Creek is not designated as a Public Water Supply (PWS), the PWS criterion for nitrate was exceeded in two samples, an indication of nonpoint source nutrient input. Ammonia was detected in all samples at concentrations slightly higher than at most other sites in the study area (0.12 mg/l average, range of 0.22-0.05 mg/l); these levels were also indicative of nutrient input.

Bean Creek

- Bean Creek drains 39.8 square miles (in Ohio) of primarily agricultural land. The average stream gradient is 3.0 feet per mile. Bean Creek receives no point source discharges from NPDES permitted entities in Ohio.

- Exceedences of Ohio WQS in Bean Creek at RM 2.2 were limited to the Secondary Contact Recreation criterion for fecal coliform bacteria (Table 5) on July 13, 1992, during high flow conditions following a large storm event (Figure 5). The high fecal coliform count was likely due to nonpoint source runoff and soil bacteria interference. Although Bean Creek is not designated as a Public Water Supply, the human health criterion for nitrate was also exceeded in the July 13 sample, which suggested nonpoint source nutrient input.

Mill Creek

- Mill Creek drains 40.3 square miles (8.3 sq. mi. in Michigan) of predominately agricultural land. Harrison Lake is an impoundment located on Mill Creek at RM 27.1. The average stream gradient is 8.4 feet per mile. Mill Creek receives an NPDES permitted discharge from the Harrison Lake State Park WWTP at RM 5.0, just downstream of the dam spillway.

- Surface water samples were collected in Mill Creek at RM 7.9 (upstream from Harrison Lake), and RM 1.8 (downstream from Harrison Lake). The only exceedence of Ohio WQS was a high fecal coliform count (Table 5) at RM 7.9 on July 13, 1992. This sample was collected immediately following a large storm event (Figure 5), so the high fecal coliform count was likely due to nonpoint source runoff and soil bacteria interference.

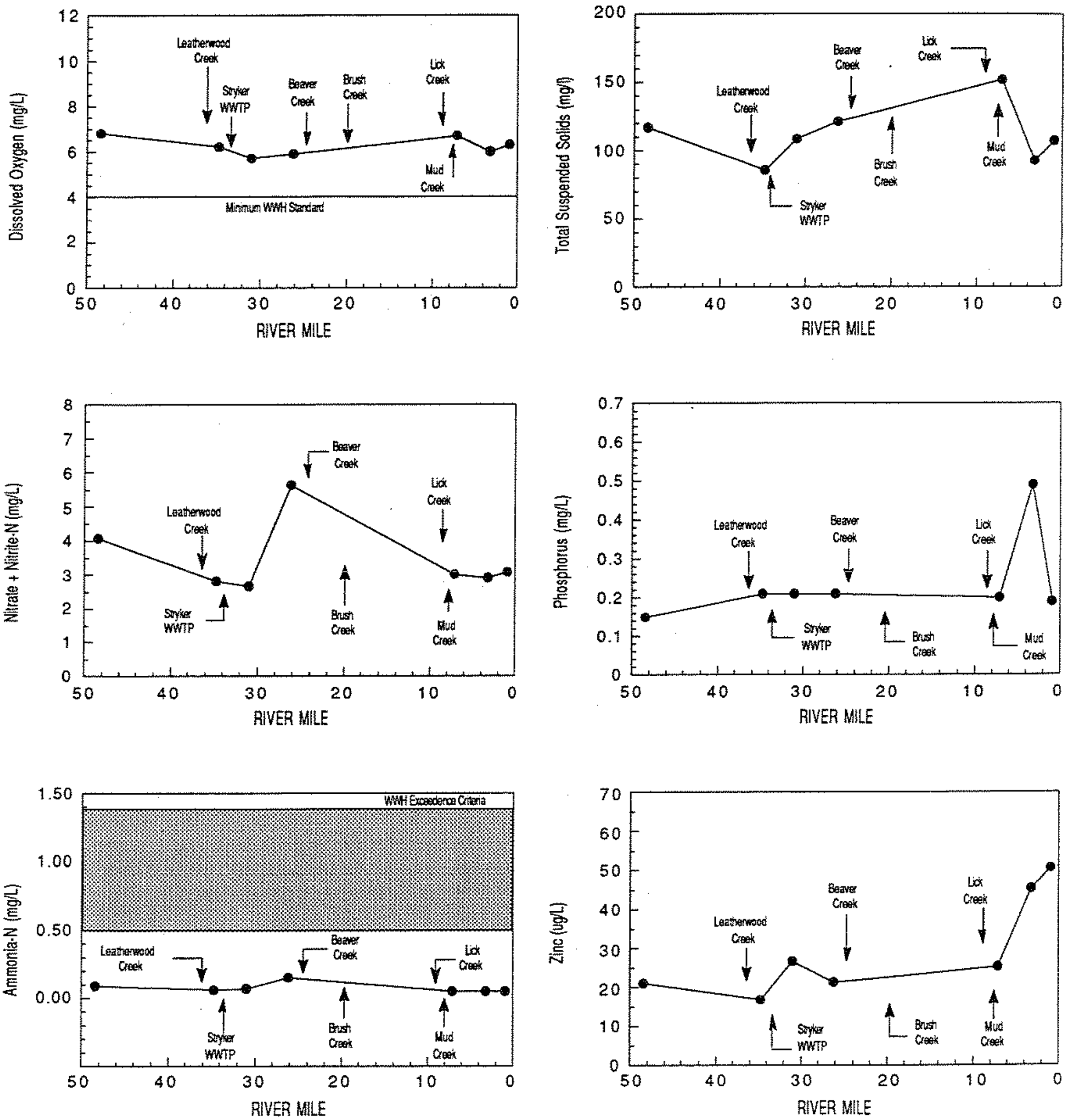


Figure 7. Longitudinal trend of mean dissolved oxygen, total suspended solids, nitrates, phosphorus, ammonia-N and zinc concentrations in the Tiffin River, 1992. Shaded area in ammonia plot (bottom left) represents the range of WQS criteria based on 90th and 25th percentile temperature and ph levels from the study area.

Sediment Chemistry

Tiffin River

- Five sites in the Tiffin River were selected for chemical analysis of sediments. These sites were located at RMs 35.3, 26.2, 7.1, 3.2 and 0.9. Fine surface silt deposited in slack water areas was targeted for collection. Results of Tiffin River sediment analyses are summarized in Tables 6 and 7.

- The sites at RMs 35.3 and 26.2 were characterized by a predominance of silt material in the substrates. At RM 7.1, a hardpan substrate was also present. Cobble and gravel was the predominant substrate at RM 3.2. At RM 0.9, upstream from the confluence with the Maumee River, a combination of silt and lake bed derived muck was the characteristic substrate.

- Based on the stream sediment classification system described by Kelly and Hite (1984), contamination from metals does not seem to be a serious concern in the Tiffin River. However, the elevated levels of zinc, lead, and iron and the elevated and highly elevated levels of chromium documented were uncharacteristic of a predominantly rural watershed. Only chromium at RMs 26.2, 7.1, and 0.9 was ranked as highly elevated (Table 6). Sediment collected at RM 35.3 contained elevated levels of zinc, iron, and chromium. Although the Village of West Unity WWTP, which discharges to Walnut Creek, is located upstream from this sampling location, it is not a likely source since there are no pretreatment industries present which would contribute these contaminants. These elevated levels are probably the result of atmospheric deposition, stormwater runoff, and natural sources. Sediment collected at RM 26.2 contained elevated levels of zinc, lead and iron and highly elevated levels of chromium. This sampling location is downstream from the Village of Stryker WWTP, which consists of a series of two aerated wastewater treatment lagoons. Unless polymers are added and pH adjustments made, these systems are not efficient at removing metals. A probable source of metals to the Stryker WWTP is the Esto Corporation, which manufactures steel tubing. This facility had a pretreatment discharge to the sanitary sewer system before 1990, when a closed loop recycle cooling system was installed. The remaining sampling locations at RMs 7.1, 3.2, and 0.9 are downstream from tributaries that receive NPDES discharges from the City of Bryan WWTP (Lick Creek via Prairie Creek) and the Village of Archbold WWTP (Brush Creek). Archbold has two pertreatment industries categorized as metal finishers and Bryan has four industries also categorized as metal finishers.

- Contamination from organochlorine insecticides does not seem to be a significant concern in the Tiffin River (Table 7). Because of the intensive use of land for agricultural crops in the Tiffin River basin, the presence of some residual concentrations of these compounds is expected. Only dieldrin at RM 35.3 and 26.2 was ranked as slightly elevated using the Kelly and Hite criteria. All other detected compounds were ranked as non-elevated.

- Polycyclic aromatic hydrocarbons (PAHs) are a widespread class of chemicals that are produced during the combustion of fossil fuels. They are also known to occur naturally as a byproduct of plant biosynthesis. These compounds are a significant concern since many are known or suspected carcinogens or cocarcinogens. No PAHs were detected in sediments at sampled sites in the Tiffin River.

- Phthalate ester plasticizers are used in virtually every major industrial product category, resulting in a wide possible distribution of this compound. As a result, they are general contaminants of nearly all soil and water ecosystems. This class of chemicals also contains many known or suspected carcinogens. A phthalate compound, Di-N-Butyl-Phathalate (1.0 ppm), was detected at RM 0.9

Table 6. Sediment concentrations (mg/kg dry weight) of eight metals in the 1992 Tiffin River study area. Concentrations (excluding nickel) were ranked based on a stream sediment classification system described by Kelly and Hite (1984). The Kelly and Hite classification system addresses relative concentrations, but does not directly assess toxicity.

River Mile	As	Cd	Cr	Cu	Fe	Pb	Ni	Zn
35.3	8.44[b]	0.563[b]	31.6[c]	25.5[a]	25,000[c]	31.3[b]	30.7	114[c]
26.2	8.45[b]	0.634[b]	**39.3[d]**	29.9[a]	28,200[c]	41.1[c]	36.0	127[c]
7.1	7.66[a]	0.480[a]	**40.1[d]**	27.0[a]	28,600[c]	20.4[a]	41.1	104[c]
3.2	8.38[b]	0.328[a]	18.6[b]	16.7[a]	16,800[a]	26.7[a]	23.3	64[a]
0.9	8.91[b]	0.514[b]	**45.8[d]**	28.0[a]	31,700[c]	38.1[c]	42.6	125[c]

[a] Non-elevated; [b] Slightly elevated; [c] Elevated; [d] **Highly elevated**; [e] **Extremely elevated**

Table 7. Tiffin River sediment priority pollutant scan detections during 1992. Corrected method detection limits, based on weight and dilution of sample, for non detected (ND) priority pollutants are presented in parentheses.

RIVER MILE **PARAMETER**	35.3	26.2	7.1	3.2	0.9
PHTHALATES (mg/kg)					
Di-N-Butyl Phthalate	ND (0.8)	ND (1.0)	ND (0.8)	ND (0.6)	1.0
PESTICIDES [1, 2] (ug/kg)					
d-BHC	2.04	2.08	1.51	1.12	1.58
Dieldrin	3.52[b]	5.20[b]	3.43[a]	2.22[a]	3.39[a]
Aldrin	ND (0.72)	1.27	ND (0.70)	ND (0.61)	ND (0.79)
Methoxychlor	ND (3.60)	ND (4.05)	ND (3.51)	3.40	ND (3.94)
DDT(sum)	ND (0.72)	ND (0.81)	1.26[a]	ND (0.61)	0.91[a]

1. All pesticide concentrations, unless indicated, were ranked with the following stream sediment classification system described by Kelly and Hite (1984).
   [a] Non-elevated; [b] Slightly elevated; [c] Elevated; [d] **Highly elevated**; [e] **Extremely elevated**; [f] Not evaluated by Kelly and Hite
2. Sum DDT is the total of 4, 4' - DDE, 4, 4' - DDD, and 4, 4' - DDT.

Fish Tissue

Tiffin River

Fish tissue samples were collected from the Tiffin River at two fish community sampling stations during 1992. Whole body composite samples of common carp and composite skin-off filet samples of channel catfish were collected from RM 48.4 (upstream from US 20 A), and RM 14.1 (upstream from Stever Road). Tissue samples were analyzed for mercury, priority pollutant pesticides (residues and metabolites), and seven polychlorinated biphenyl (PCB) mixtures (Table 8).

Tissue samples of both species (common carp and channel catfish) from all sampling stations contained mercury above detection limits. However, these values were well below the FDA action limit of 1000 µg/kg (Table C). Over 50% of the pesticides analyzed were either not present or were below detection levels in all tissue samples collected. Detected parameters (dieldrin, DDT metabolites) in channel catfish and common carp were well below FDA action level at all sampling stations. Six of the seven PCB mixtures were either not present or were below detection levels in all common carp and channel catfish tissue samples. Aroclor-1260 (PCB-1260) was detected at both sampling stations in all tissue samples; however, these values were well below the FDA action level for total PCBs (2 mg/kg).

Table 8. Summary of contaminant levels in fish tissue samples collected from the Tiffin River during 1992. All results are reported in mg/kg (NA - not analyzed, ND - below detection levels).

River/stream Parameter	RM 48.4 3-channel catfish (composite skin-off fillet)	RM 48.4 5-common carp (whole body)	RM 14.1 5-channel catfish (composite skin-off fillet)	RM 14.1 3-common carp (whole body)
Tiffin River				
Mercury	.198	.0733	.122	.0657
Aldrin	ND	ND	ND	ND
a-BHC	ND	ND	ND	ND
b-BHC	ND	ND	ND	ND
d-BHC	ND	ND	ND	ND
y-BHC	ND	ND	ND	ND
4,4'-DDD	.0061	.0330	.0362	.00628
4,4'-DDE	.0139	.0641	.0226	.0174
4,4'-DDT	ND	ND	ND	ND
Dieldrin	.0362	.0844	.0618	.0645
Endosulfane I	ND	ND	ND	ND
Endosulfane II	ND	ND	ND	ND
Endosulfane Sulfate	ND	ND	ND	ND
Endrin	ND	ND	ND	ND
Endrin Aldehyde	ND	ND	ND	ND

Table 8. (continued).

River/stream Parameter	RM 48.4 3-channel catfish (composite skin-off fillet)	RM 48.4 5-common carp (whole body)	RM 14.1 5-channel catfish (composite skin-off fillet)	RM 14.1 3-common carp (whole body)
Heptachlor	ND	ND	ND	ND
Heptachlor Epoxide	ND	ND	ND	<.00396
Methoxychlor	ND	<.00911	ND	ND
Mirex	ND	ND	ND	ND
Hexachlorobenzene	ND	ND	ND	ND
Chlordane	ND	NA	ND	NA
Toxaphene	ND	ND	ND	NA
PCB-1016	ND	ND	ND	ND
PCB-1221	ND	ND	ND	ND
PCB-1232	ND	ND	ND	ND
PCB-1242	ND	ND	ND	ND
PCB-1248	ND	ND	ND	ND
PCB-1254	ND	ND	ND	ND
PCB-1260	.0496	.0954	.0582	.0381

Physical Habitat for Aquatic Life

Tiffin River

The Tiffin River mainstem and tributaries have been subject to significant channel and riparian zone modification. During the late nineteenth and early twentieth century, the mainstem and tributaries in the upper portion of the watershed were systematically modified to increase surface and subsurface drainage. Alterations to the Tiffin River mainstem and tributaries included, but were not limited to: the removal of natural meanders, complete relocation of the active channel, limited channel dredging, and channelization of most of the smaller tributaries. Though systematic, basinwide channel modifications have not been conducted for nearly ninety years, these drainage modifications have been maintained to some extent since the mid-1960s (Fulton County Engineer's Office, pers. comm.).

Information about the degree and extent of channel modification within the lower portion of the Tiffin River basin was not available from the Williams and Defiance County Engineers. However, based on field observations it was evident that the lower segment of the study area has been subject to systematic, channel modification similar to that encountered within the upper portions of the watershed in Fulton County.

The activities described above have had profound influences upon macrohabitats and the aquatic communities of the Tiffin River. Pervasive siltation and monotonous channel development were considered the most significant factors presently affecting the basin. Given the agricultural land use and drainage modification associated with intensive cultivation, clayey silts are rapidly delivered to and retained within this low gradient system. With an average gradient of 1.2 feet/mile (Ohio DNR 1960) and local gradients as low as 0.47 feet/mile, the retention time of suspended and bedload sediments is high and allows for the excessive deposition of fine silts. The resulting accretion has degraded instream habitats by reducing depth heterogeneity and severely embedding coarse substrates, effectively eliminating major components of riverine habitat.

The Tiffin River has shown only moderate recovery from past channel modification. Generally, river systems of sufficient gradient will reestablish free flowing characteristics over time if left undisturbed following channelization. In contrast, the low gradient and the highly modified character of the Tiffin River watershed coupled with the significant encroachment of adjacent land uses into the riparian zone, virtually precludes full recovery of original stream habitats. However, natural fluvial processes have resulted in **limited** recovery of some of the habitat deficit encountered within the basin. In these areas where downed timber and large woody debris have collected and become relatively stable, the low flow is constricted, resulting in a local and sustained increase in current velocity. Under these conditions, swift run habitats are maintained. Generally, the constricted flow keeps the coarse substrates swept free of excessive silts. The large woody debris also functions to provide critical macro and micro habitat for aquatic organisms and encourages flow variation and scouring of pools. These swiftly flowing areas provided critical refugia for many sensitive species associated with mixed current velocities and clean coarse substrates. Relatively stable, flow constricting woody debris represents the majority of functional habitat remaining within the Tiffin River mainstem.

During the 1992 survey macrohabitats of the Tiffin River were evaluated at seven fish sampling stations. Qualitative Habitat Evaluation Index (QHEI) values ranged from 36 at RM 35.4 to 53 at RM 31.0, with a mean reach value of 45.4. A mean reach QHEI score less than 45.0 suggests that near and instream habitats of the Tiffin River may inhibit full attainment of the WWH use criteria (Rankin 1989).

Moderate and high influence modified habitat attributes predominated throughout the Tiffin River (Table 9). The high frequency of occurrence of these attributes reflected the highly modified character of the watershed. Limiting components of habitat included: extensive embedding of native substrates with clayey silts, past channelization, and fair/poor channel development.

The poorest habitat within the Tiffin River was encountered at RM 35.4 with a QHEI score of 36. Except for pooled areas greater than 40 cm in depth, moderate and high influence modified habitat attributes were exclusively encountered (Table 9). This station displayed little recovery from past channel modification, and was the only site not containing significant (flow constricting) woody debris. Monotonous channel development, pervasive siltation, and the lack of functional instream cover presently limit ambient biological potential at this station.

The remainder of the Tiffin River study area was characterized by physical similar habitats of similar quality. However, excepting RM 35.4, most of the sampling stations included at least one stable deadwood snag. As outlined above, this component of instream structure contributed significantly to habitat heterogeneity and resulted in some localized mitigation of habitat loss due to drainage modification (past and maintained) and agricultural nonpoint sources (primarily deposition of clayey silts).

Mill Creek
Macrohabitats of Mill Creek were evaluated at two fish sampling stations during the 1992 field sampling efforts. Qualitative Habitat Evaluation Index values were 62.5 at RM 2.0 (downstream of Harrison Lake) and 58.5 at RM 8.0 (upstream from Harrison Lake); the average QHEI value was 60.5. The mean QHEI value suggests that near and instream habitats of Mill Creek are of sufficient quality to support and maintain a community of aquatic organisms capable of attaining the WWH biological criteria (Rankin 1989).

Habitat at the sampling station at RM 8.0 (upstream from Harrison Lake) consisted of a predominance of moderate and high-influence modified attributes (Table 9). Though modified habitat attributes were abundant, some components of good quality habitat were maintained. Warmwater attributes observed at this station included: abundant glacial cobble, no recent channelization (or near complete recovery from past channel work), and pooled areas greater than 40 cm in depth. Limiting aspects of instream habitat included: moderate siltation, fair to poor channel development, and sparse instream cover. Though habitat for aquatic life was less than optimal at this station, impairment of the WWH use designation based solely on habitat quality did not appear at all likely.

Habitat quality at RM 2.0 (downstream from Harrison Lake) was improved over RM 8.0. Warmwater habitat attributes occurred at a greater frequency than moderate influence modified attributes; high influence modified attributes were absent (Table 9). Habitat at this sampling reach consisted of: coarse glacial substrates, good/fair channel development, pools greater than 40 cm in depth, and high/moderate functional sinuosity. Near and instream habitats at this station appeared capable of supporting an aquatic community able to achieve the WWH biological criteria.

Old Bean Creek
Macrohabitats of Old Bean Creek were evaluated at one fish sampling station at RM 1.7 (downstream from Old Angola Road). This site achieved a QHEI score of 29.5 and reflected the previous channelization (relocation of the active channel *circa* 1900) and on-going channel maintenance activities (Fulton County Engineers, pers. comm.). Moderate and high influence modified habitat attributes were overwhelmingly predominant (Table 9). Limiting aspects of instream habitat included: extensive deposition of clayey silts, sparse instream cover, poor channel development, and low functional sinuosity.

Given the prevailing modified habitat characteristics, channel maintenance activities, and the low average gradient (1.63 feet/mile) it is unlikely that Old Bean Creek has the potential to recover . Consequently, Old bean Creek did not appear capable of supporting WWH aquatic communities.

Bean Creek
Macrohabitats of Bean Creek were evaluated at one fish sampling station at RM 2.3 (upstream of Old Angola Road); a QHEI score of 50 was achieved. Though near and instream habitats were less than optimal, a predominance of warmwater habitat attributes was observed (Table 9).

Despite a history of significant channel modification, including a complete relocation of the active channel in 1906 (Fulton County Engineers, pers. comm.), Bean Creek appeared to have acquired many free flowing habitat characteristics. Components of quality stream habitat observed during the assessment included: good/fair channel development, moderate sinuosity, pools greater than 40 cm in depth, mixed current velocities, and substrates relatively free of excessive silt deposition (Table 9). The factors responsible for this phenomenon appeared to be related to groundwater inputs and possibly favorable land use practices within the upper reaches in southern Michigan.

Regardless of the ultimate cause(s), swift currents were maintained though local gradients were not elevated in comparison to other stream segments within the study area. The continuous flow observed throughout the 1992 sampling effort appeared to contribute significantly to the creation and maintenance of functional instream habitat.

Table 9. Qualitative Habitat Evaluation Index (QHEI) matrix showing modified and warmwater habitat characteristics for the Tiffin River study area, July - September, 1992.

Key QHEI Components

			WWH Attributes											MWH Attributes: High Influence						Moderate Influence														
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/ Eddies	Low/Normal Embeddedness	Max Depth > 40 cm	Low/No Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD,HW)	Total H.I. MWH Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Moderate Embeddedness	Ext./Moderate Riffle Embed.	No Riffle	Total M.I. MWH Attributes	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
(04-600) – Tiffin River																																		
Year: 92																																		
47.6	49.5	1.60	■				■				■		3		●				1	▲	▲			▲	▲			▲	▲		▲	7	.50	2.25
35.4	36.0	.64									■		1		●		●		2	▲	▲			▲	▲			▲	▲		▲	7	1.50	5.00
31.0	53.0	.83	■			■	■	■			■	■	6		●				1	▲	▲			▲					▲			4	.29	.86
26.0	47.5	.83	■			■	■	■			■		5		●				1	▲	▲			▲					▲		▲	5	.33	1.17
14.1	43.5	.47				■	■				■		3		●		●		2	▲	▲			▲				▲	▲		▲	6	.75	2.25
6.9	45.0	.47				■		■			■		4		●		●		2	▲	▲			▲	▲				▲			5	.60	1.60
1.1	43.0	.47				■	■				■		3		●		●		2	▲	▲			▲	▲			▲	▲		▲	7	.75	2.50
(04-624) – Mill Creek																																		
Year: 92																																		
8.0	58.5	4.95	■	■							■		3				●		1		▲			▲	▲			▲	▲	▲		6	.50	2.00
2.0	62.5	3.50	■	■		■	■	■		■	■	■	8						0	▲				▲				▲				3	.11	.44
(04-626) – Bean Creek																																		
Year: 92																																		
2.3	50.0	1.16	■			■	■		■	■	■		6				●		1					▲	▲						▲	3	.29	.71
(04-632) – Old Bean Creek																																		
Year: 92																																		
1.7	29.5	1.63									■		1		●		●		2	▲	▲			▲	▲			▲	▲		▲	7	1.50	5.00

Biological Assessment: Macroinvertebrate Community
Tiffin River

- Artificial substrate samples were collected at six Tiffin River stations from RMs 47.6 to 0.9 (Table 10; Figure 8). Narrative evaluations ranged from exceptional at RMs 47.6, 26.2 and 7.1 (ICIs = 50-54) to the lower good range at RM 35.4 and 0.9 (ICIs = 34). Although the artificial substrates were lost at station RM 14.2, the site was evaluated as marginally good based on qualitative (natural substrate) sampling. Siltation appeared pervasive throughout most of the mainstem, particularly in pooled habitats and along wide margin areas where strong currents were lacking. Consequently, sampling was the most productive in those limited areas where sufficient current velocity prevented excessive silt deposition and from woody debris suspended above the soft, bottom sediments.

- Lower ICI scores from RMs 35.4 and 0.9 were considered primarily related to reduced current velocities over the artificial substrates and subsequent increases in silt and muck deposition. Samplers collected from areas of stronger flow were predominated by more pollution sensitive and flow-dependent mayfly and caddisfly populations, while in areas of slower current, more silt-tolerant dipteran and non-insect populations predominated. Station RM 35.4 was in a recently channelized section near the SR 91 bridge while flows at the RM 0.9 site were affected by an impoundment effect created by the Defiance Dam. Natural substrate communities at RM 14.2 also suggested negative impacts due to severe bank slumpage and erosion adjacent to the river and monotonous clay/hardpan substrates. Overall, all ICI scores achieved the WWH criterion and reflected no serious water quality problems in the mainstem.

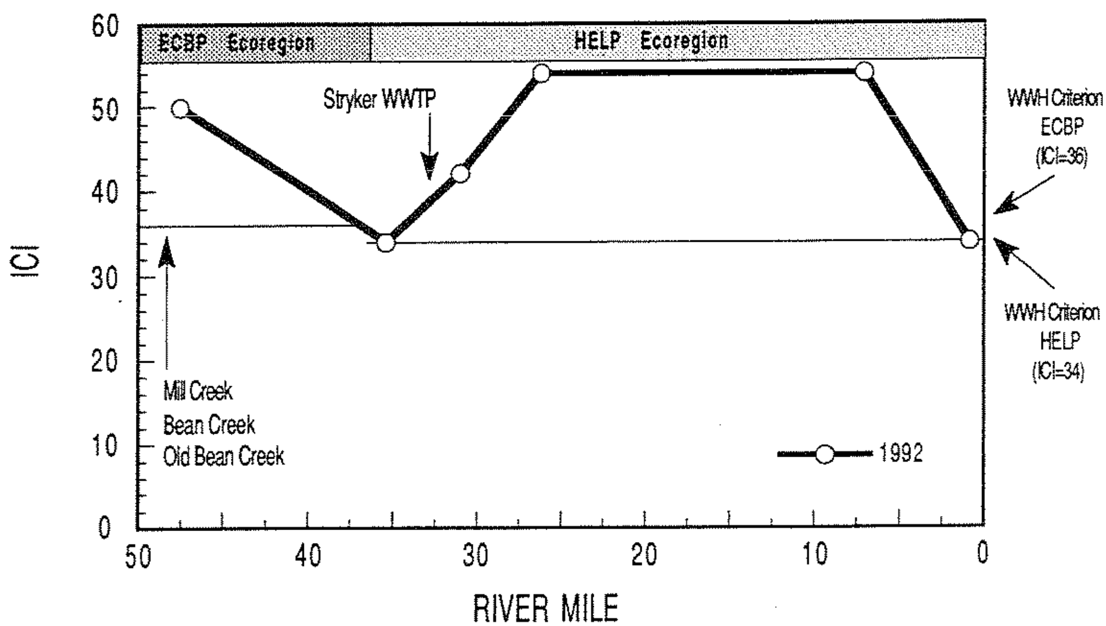


Figure 8. Longitudinal trend of the Invertebrate Community Index (ICI) in the Tiffin River (station RMs 47.6-0.9), 1992.

Table 10. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Tiffin River basin, July - September, 1992.

Stream River Mile	Relative Density	Quant. Taxa	Qual. Taxa	Qual. EPT[a]	QCTV[b]	ICI	Narrative Evaluation[c]
			Quantitative Evaluation				
Tiffin River							
47.6	972	43	32	16	32.8	50	Exceptional
35.4	383	44	28	7	34.0	34	Good
31.0	354	48	29	11	37.5	42	Good
26.2	515	44	28	13	40.9	54	Exceptional
7.1	805	44	39	15	38.8	54	Exceptional
0.9	528	43	32	7	35.4	34	Good

Stream River Mile	No. Qual. Taxa	QCTV[b]	Qual. EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation[c]
			Qualitative Evaluation			
Tiffin River						
14.2	21	42.4	12	Low	Caddisflies	Marg. Good
Mill Creek						
7.9	53	37.4	12	Mod-High	Caddisflies, isopods	Good
2.0	44	34.7	9	Low	midges	Marg. Good
Bean Creek						
2.2	35	41.3	.14	Mod	Caddisflies, midges, baetid mayflies	Good
Old Bean Creek						
1.9	25	28.8	2	Low	Red midges	Poor

* Significant departure from ecoregional biocriteria (>4 ICI units); poor and very poor results are underlined.
ns Nonsignificant departure from ecoregional biocriterion (≤4 ICI units).
a EPT= total Ephemeroptera (mayflies), Plectoptera (stoneflies) and Tricoptera (caddisflies).
b QCTV derived as the median of the tolerance values calculated for each qualitative taxon present.
c A qualitative narrative evaluation based on best professional judgement is used when quantitative data is not available to calculate the Invertebrate Community Index (ICI) scores.

Ecoregion Biocriteria: E. Corn Belt Plains (ECBP) / Huron-Erie Lake Plain (HELP)

INDEX	WWH	EWH	MWH[d]
ICI	36/34	46/46	22/22

d - Modified Warmwater Habitat for channel modified areas.

- The Stryker WWTP had no discernible impact on invertebrate communities sampled 1.6 miles downstream. The ICI of 42 at RM 31.0 was in the very good range and not indicative of any significant point source impacts.

Mill Creek

- Qualitative samples were collected from Mill Creek upstream from Harrison Lake (RM 7.9) and downstream near the confluence with the Tiffin River (RM 2.0). Narrative evaluations ranged from good at the upstream site to marginally good downstream. Slight declines in community performance from upstream to downstream appeared related to low habitat diversity (all pool), monotonous sand substrate conditions, and more extensive channelization at the downstream site. At RM 7.9, dense populations of hydropsychid caddisflies and isopods suggested moderate nutrient enrichment while substrate embeddedness and extensive areas of failing banks were indications of excessive sedimentation from agricultural sources and the negative effects of past channelization activity. The Qualitative Community Tolerance Value (QCTV) scores for RM 7.9 (37.4) and 2.0 (34.7) fell into an intermediate performance range. Ranges were based on historical ecoregional data from sites attaining the WWH aquatic life use (good to exceptional ranges) and sites not attaining (fair to poor ranges) as determined by the ICI (Figure 9).

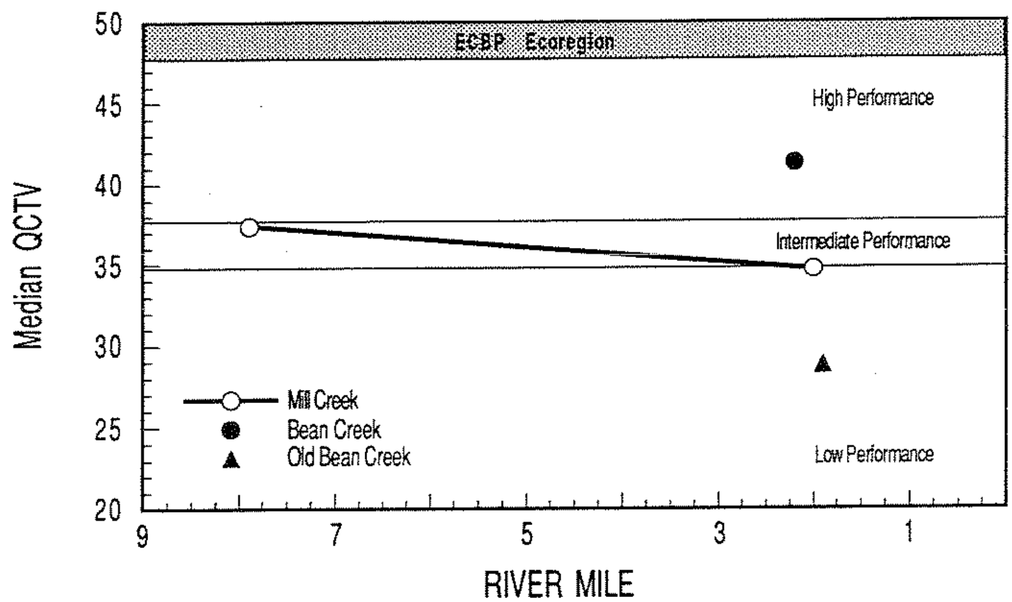


Figure 9. Longitudinal trend of the Qualitative Community Tolerance Values (QCTV) in Mill Creek, Bean Creek and Old Bean Creek, 1992. High performance scores exceed the 25th percentile QCTV of attaining sites in Ohio based on the ICI. Low performance scores fall below the 75th percentile QCTV of Ohio sites not attaining based on the ICI.

Bean Creek

- Bean Creek RM 2.2 was channelized with predominantly sand substrates but contained discernable riffle, run and pool habitats. The QCTV score of 41.3 suggested high macroinvertebrate community performance, well above minimum levels associated with historical sites that exceeded the WWH biocriterion (Figure 9). The community was moderately diverse (35 taxa) and was predominated by hydropsychid caddisflies and mayflies (Qual. EPT=14). The macroinvertebrate community was evaluated as good and reflected acceptable water quality and habitat conditions.

Old Bean Creek

- The site at RM 1.9 was channelized, nearly stagnant, and filled with silt. Sampling yielded 25 total taxa, two EPT taxa, and a predominance of hemoglobin bearing (red) midges of the genus *Tribelos*. *Tribelos* larvae commonly inhabit the littoral sediments of lakes (Wiederholm, 1983). The QCTV of 28.8 showed community performance was well below the ecoregional minimum expectation as determined by the 75th percentile QCTV score of ECBP sites failing to achieve the ICI biocriterion (Figure 9). Overall, the benthic community was considered poor and severely impacted by siltation and habitat modifications.

Biological Assessment: Fish Community

Tiffin River

- A total of 3,927 fish comprised of 44 species was collected from the Tiffin River between July and September, 1992. The sampling effort included seven sampling stations within a 46.5 river mile stretch from RM 47.6 (downstream from the confluence of Bean Creek and Mill Creek) to RM 1.1 (near the mouth).

- Community indices and corresponding narrative evaluations ranged from marginally good (IBI=40; MIwb=8.2) at RM 47.6 to fair (IBI=31; MIwb=7.8) at RM 26.0 and RM 14.0 (Table 11). Exceptional or very poor performance was not observed at any site. Viewed in total (all sampling locations), community performance was characterized as mostly fair.

- Fish species that were numerically predominant included: spotfin shiner (34.6%), gizzard shad (16.5%), orangespotted sunfish (11.4%), bluntnose minnow (8.6%), and common carp (4.8%). Species that predominated in terms of biomass were: common carp (62.0%), silver redhorse (10.5%), channel catfish (6.3%), golden redhorse (5.9%), and fresh water drum (3.7%).

- In terms of relative abundance, the fish community was predominated by species that, due to their particular life histories, have maintained the ability to thrive in areas subjected to significant physical modification (*e.g.*, channelization, siltation, and impoundment). The spotfin shiner is tolerant of a variety of habitats. However, this species tends to occur in the greatest abundance in systems of base or low gradient, and is often numerically predominant in silted and turbid waters (Trautman 1981, Becker 1983). The gizzard shad is commonly associated with lakes, oxbows, and impoundments, or rivers of basic or low gradient (Trautman 1981). The orangespotted sunfish is a species strongly associated with low gradient turbid river systems where there is considerable silt deposition (Trautman 1981, Smith 1979, and Becker 1983). The remaining species that were numerically predominant (common carp and bluntnose minnow) are highly tolerant of modified habitats and water quality perturbations (Ohio EPA 1987b). Though the most abundant fish species within the Tiffin River are not classified as highly tolerant, these species have displayed a marked preference for low gradient and/or silted, physically disturbed waters. The abundance of these and other tolerant forms reflected the pervasive modified habitat characteristics of the Tiffin River system.

Table 11. Fish community indices based on pulsed D.C. electrofishing samples from 11 locations in the Tiffin River basin during July - September, 1992. Sites were sampled using the boat method (Tiffin River, Bean Creek and Old Bean Creek) and the wading method (Mill Creek).

Stream River Mile	Mean Number of Species	Mean Cumulative Species	Mean Rel. No. (No./Km)	Rel. Wt. (Kg/Km)	QHEI	Mean Modified Index of Well-Being	Mean Index of Biotic Integrity	Narrative Evaluation[a]
Tiffin River								
47.6	25.5	33	1088	102.6	49.5	8.2[ns]	40[ns]	M. Good
35.4	16.5	23	313	39.54	36.0	6.3*	29*	Poor/Fair
31.0	18.5	25	589	59.09	53.0	7.7*	37	Fair/M.Good
26.0	18.0	22	386	50.03	47.5	7.8*	31[ns]	Fair
14.1	17.5	21	299	66.36	43.5	7.8*	31[ns]	Fair
6.9	20.0	24	481	49.60	45.0	8.0*	36	Fair/M.Good
1.1	20.0	27	759	35.34	43.0	7.9*	36	Fair/M.Good
Bean Creek								
2.3	25.0	30	469	126.2	50.0	8.0[ns]	41	M.Good/Good
Old Bean Creek								
1.7	20.0	25	362	77.82	29.5	8.0[ns]	33*	M.Good/l
Mill Creek								
8.0	9.5	11	1683	7.119	58.5	6.4*	<u>19</u>*	Fair/Poor
2.0	25.5	31	1523	12.00	62.5	7.2*	30*	Fair

Ecoregion Biocriteria: Eastern Corn Belt Plains (ECBP)

INDEX - Site Type	WWH	EWH	MWH[d]
IBI - Headwaters/Wading	40	50	24
IBI - Boat	42	48	24
Mod. Iwb - Wading	8.3	9.4	5.8
Mod. Iwb - Boat	8.5	9.6	5.8

Ecoregion Biocriteria: Huron-Erie Lake Plain (HELP)

INDEX - Site Type	WWH	EWH	MWH[d]
IBI - Boat	34	48	20
Mod. Iwb - Boat	8.6	9.6	5.7

[d] - Modified Warmwater Habitat for channel modified areas.

a -Narrative evaluation is based on both MIwb and IBI scores.

* -Significant departure from applicable biological criterion (>4 IBI units or >0.5 Iwb units); underlined values are in the poor and very poor range.

ns -Nonsignificant departure from biocriterion (<4 IBI units or < 0.5 MIwb units)

NA -Headwater site; MIwb is not applicable.

- To a large extent, instream physical habitat appeared to exert significant influence on local (site specific) fish community performance. Without question, the most influential aspects of instream habitat within the Tiffin River were deadwood snags. Given the relatively monotonous channel development and pervasive siltation, resulting from extensive past channel modification and current land use practices, these swiftly flowing areas formed by woody debris provided critical refugia for sensitive (lithophilic and insectivorous) fishes. The vast majority of fish collected within the Tiffin River during the field sampling effort were strongly associated with this habitat.

- The fish community at the most upstream sampling station (RM 47.6) performed at a marginally good level (IBI=40; MIwb=8.2), fully achieving WWH biological criteria (Figure 10). Diminished community performance was observed at RM 35.4 (upstream Stryker WWTP), and appeared habitat related. Both community indices failed to achieve ecoregional biological criteria and received a narrative evaluation of poor/fair (Figure 10). Components of physical habitat that contributed to low performance included past channel modifications, encroachment on the riparian zone, pervasive siltation, and a lack of flow constricting deadwood snags.

- No impact within the fish community was observed downstream from the Stryker WWTP at RM 31.0. On the contrary, the fish assemblage appeared to respond to an improvement in macrohabitats at this station. In comparison to the station upstream, moderate increases in number of sucker species (particularly round bodied suckers) and percent lithophilic species were observed. The shifts within the fish assemblage at this station reflected the swift run habitats created and maintained by deadwood snags. The IBI indicated improved functional organization and achieved the ecregional biological criterion. However, the MIwb suggested that structural components remained diminished. The fair performance within the MIwb resulted in partial achievement of WWH criteria (Table 11; Figure 10) at RM 31.0.

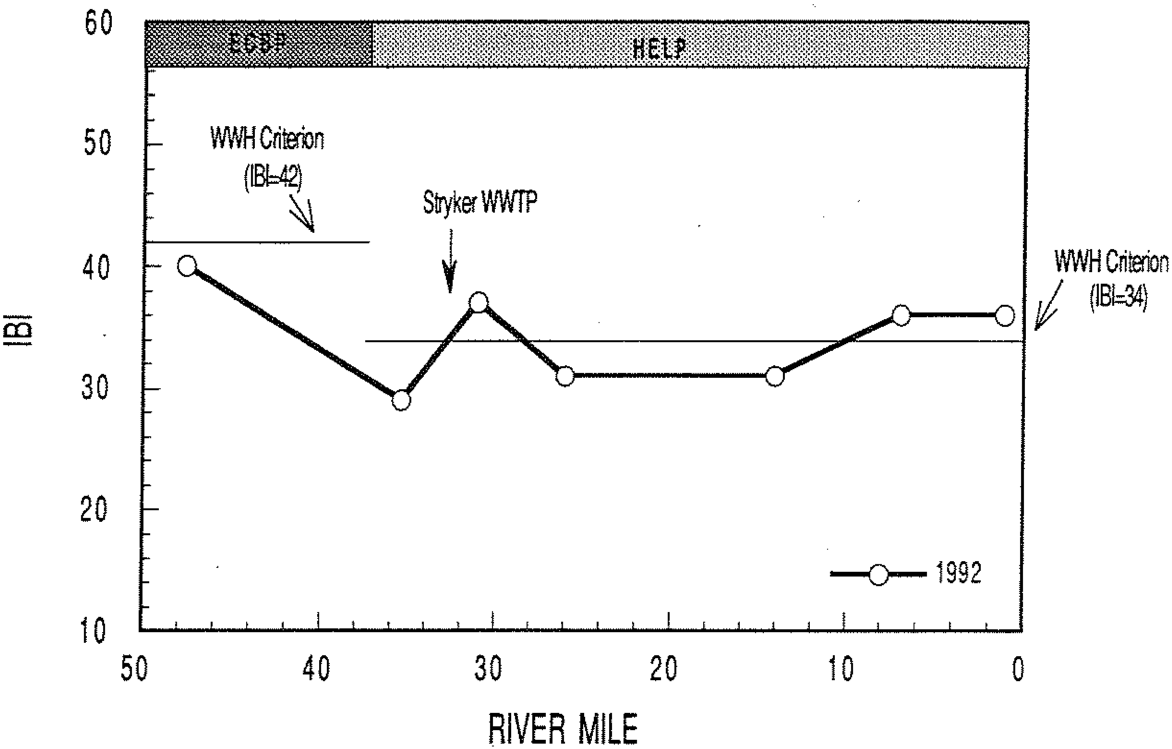
- Fish community performance in the lower portion of the study area (between RM 26.0 and RM 1.1) remained relatively stable (Figure 10). Functional components of the fish assemblage were maintained and were a reflection of instream habitat. The IBI values within this reach consistently achieved ecoregional expectations. Performance below the ecoregional biocriterion by the MIwb resulted in partial achievement of the WWH aquatic life use throughout this reach (Figure 10; Table 11).

- In summary, non and partial achievement of WWH aquatic life use biological criteria within the fish community between RMs 35.4 and 1.1 did not appear to be influenced by water quality problems associated with point source discharge. The quality and extent of near and instream habitats appeared to exert a much more significant influence on community performance.

Mill Creek

- A total of 4,272 fish comprised of 32 species was collected from Mill Creek between June and September, 1992. The sampling effort included two stations at RM 8.0 (upstream from Harrison Lake) and RM 2.0 (downstream from Harrison Lake).

- Fish species that were numerically predominant within Mill Creek included: bluntnose minnow (40.2%), creek chub (21.7%), johnny darter (15.0%), central stoneroller (7.0%), and spotfin shiner (5.1%). Species that predominated in terms of biomass were: white sucker (29.0%), creek chub (28.0%), common carp (11.4%), bluntnose minnow (8.5%), and central stoneroller



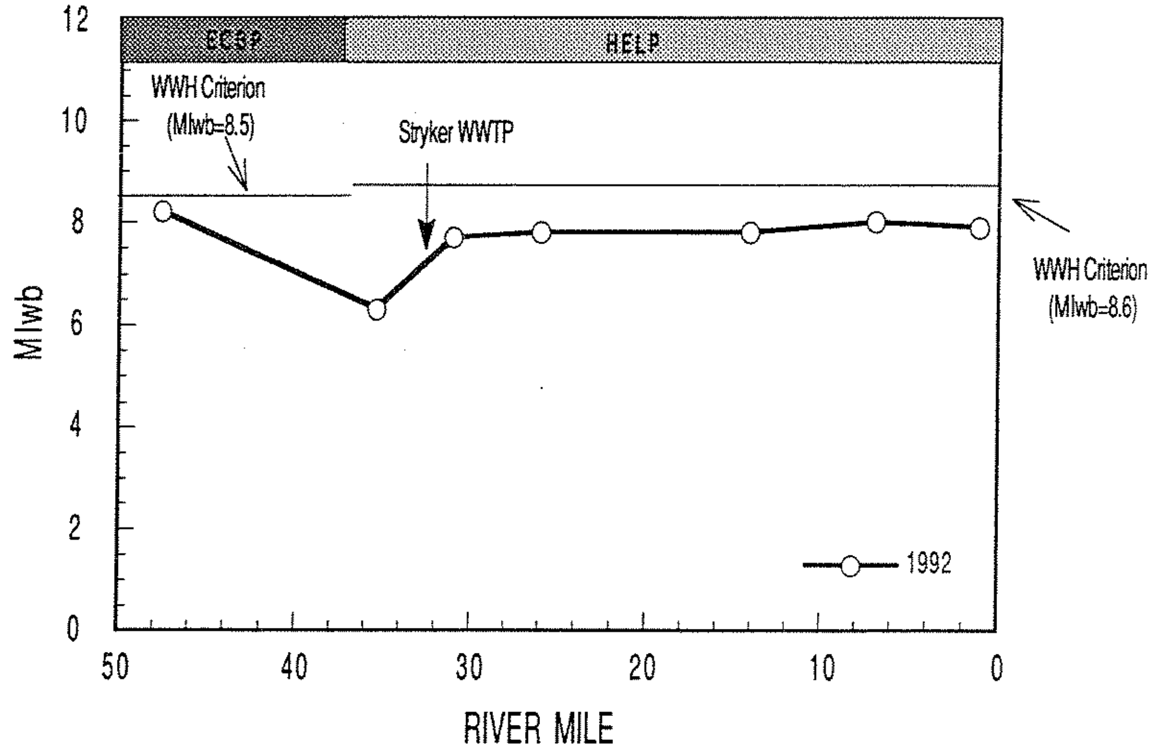


Figure 10. Longitudinal trend of the Index of Biotic Integrity (IBI; upper) and the Modified Index of Well Being (MIwb; Lower) in the Tiffin River (RM 47.6-1.1), 1992.

(4.6%). The fish assemblage was predominated in terms of relative abundance and biomass by tolerant, omnivorous and habitat generalist species.

- Fish community performance at RM 8.0 (upstream from Harrison Lake) received a narrative evaluation of fair/poor (MIwb=6.4; IBI=19) (Table 11). Both community indices failed to achieve the ecoregional WWH biological criteria. The fish assemblage at this station in terms of relative abundance and biomass was predominated by species highly tolerant of water quality perturbations and modified habitats.

- The IBI score of 19 suggested a recent temporal pollution event had impacted the fish community at RM 8.0. The fish assemblage was predominated by pioneering species such as creek chub, silverjaw minnow, bluntnose minnow, green sunfish, and johnny darter. These species are typically the first components of the community to reinvade formerly dessicated stream reaches and/or areas that have been subjected to episodic pollution events. The predominance of these species in Mill Creek suggests the fish community was recovering from a recent catastrophic event. The segment of the Mill Creek watershed upstream from Harrison Lake has a history of chemical spills (fertilizer, PCB wastes and agricultural nonpoint impacts), resulting in documented fish kills (Ohio DNR 1979-1986 and Ohio EPA ERS 1978-1992). Given the history of accidental discharges within the upper reaches of Mill Creek, it was likely that an unreported pollution event had influenced the sampling station at RM 8.0.

- Fish community performance at RM 2.0 (downstream from Harrison Lake) received a narrative evaluation of fair (MIwb=7.2; IBI=30). Both community indices failed to achieve ecoregional expectations, however, in comparison to the upstream sampling station community performance was improved. A substantial increase in species richness (particularly darters and round-bodied suckers), and the presence of intolerant species reflected modest improvements in physical habitat and improved water quality.

Old Bean Creek

- One sampling station was located on Old Bean Creek at RM 1.7 downstream from Old Angola Road. A total of 362 fish comprised of 25 species was collected between August and September, 1992. Fish species that were numerically predominant included green sunfish (17.7%), white sucker (17.4%), spotfin shiner and black bullhead (8.8%), and grass pickerel (8.6%). Species that predominated in terms of biomass were: common carp (52.1%), white sucker (22.3%), freshwater drum (9.6%), spotted sucker (5.2%), and black bullhead (2.7%).

- The fish assemblage of Old Bean Creek was predominated by highly tolerant and omnivorous species; intolerant forms were lacking. Additionally, other predominant species, though not classified as tolerant, have shown a marked preference for river systems of low or base gradient with considerable siltation and/or pooled or impounded habitats. Community performance at RM 1.7 received a narrative evaluation of marginally good/fair, partially achieving the ecoregional biocriterion (Table 11).

- Like the Tiffin River mainstem, community performance within Old Bean Creek appeared to reflect the condition of near and instream macrohabitats. Old Bean Creek has been subjected to significant channel modifications. Alterations of the physical habitats included a complete relocation of the active channel (*circa* 1900) and continued maintenance of previous channel work since the mid 1960s (pers. comm., Fulton County Engineer, 1993). Past and continued maintenance activities have resulted in monotonous channel development, extensive siltation, and embeddedness. Given the relatively small drainage area and low gradient of Old Bean Creek, it is doubtful that restoration of habitats through natural fluvial processes is realistic in the near term. Consequently, the innate character of Old Bean Creek and the need for periodic channel maintenance likely precludes full achievement of ecoregional biological criteria.

Bean Creek

- One sampling station was located on Bean Creek at RM 2.3 upstream from Old Angola Road. A total of 469 fish comprised of 30 species and one hybrid was collected between August and September, 1992. In terms of relative abundance, the fish community was predominated by: spotfin shiner (36.9%), golden redhorse (15.4%), common carp (10.0%), bluntnose minnow (5.3%), and northern hogsucker and silver redhorse (4.3%). Species that predominated in terms of biomass were: common carp (54.0%), golden redhorse (13.2%), channel catfish (9.2%) northern pike (8.0%), and silver redhorse (4.5%).

- Moderately intolerant and tolerant insectivorous and omnivorous species predominated in terms of relative abundance and biomass. Though tolerant generalist species were a significant component of the fish community (common carp and bluntnose minnow), moderately intolerant, insectivorous, and lithophilic species such as redhorse and northern hogsucker were well represented.

- Community performance at RM 2.3 received a narrative evaluation of marginally good/good and fully achieved the ecoregional biocriteria (Table 11). Community indices (IBI and MIwb) indicated structural and functional components of the fish assemblage were maintained. The community at this station was characterized by high species richness, an abundance of round-bodied suckers, and a high percentage of insectivorous and lithophilic species. Also present were species intolerant of water quality degradation and physically disturbed habitats.

- Despite a history of significant channel modification, instream macrohabitats were maintained within Bean Creek. Habitat conditions, though less than optimal, did support a fish assemblage fully achieving ecoregional performance expectations. This was due primarily to continuous flow, particularly during dry weather periods, and was an important physical characteristic lacking from other modified tributaries. This factor alone, if present in sufficient volume, can ameliorate some negative influences of channel modification.

Trend Assessment-Tiffin River

Chemical Water Quality Changes: 1984-1992

- A comparison of 1992 and 1984 chemical results in the Tiffin River indicates minimal changes in water quality conditions between the two survey years (Figure 11). Elevations of some parameters (primarily nutrients) in 1992 were almost entirely related to collections made on July 13 under rising hydrograph, high flow conditions. These elevated concentrations were indicative of temporal conditions associated with nonpoint runoff. When data were analyzed excluding the July 13 samples, mean concentrations of most nutrients were similar to, or slightly lower than those found in 1984. Some of these reductions may be related to WWTP upgrades at Stryker and Archbold (discharge to Brush Creek) since 1984. The ongoing trend in the basin of conversion to reduced tillage farming practices may also have helped reduce background nutrient levels in the Tiffin River. This trend should become more apparent in future surveys conducted over the next five to ten years.

- Exceptions to the above observations were sharp increases in zinc and phosphorus noted in the lower 3.2 miles of the mainstem. These increases suggest the presence of an unidentified pollution source in the lower mainstem.

- Overall, nutrient enrichment within the Tiffin River watershed caused by ammonia, nitrate, and total phosphorus did not appear to present a major concern based on the data collected in 1992.

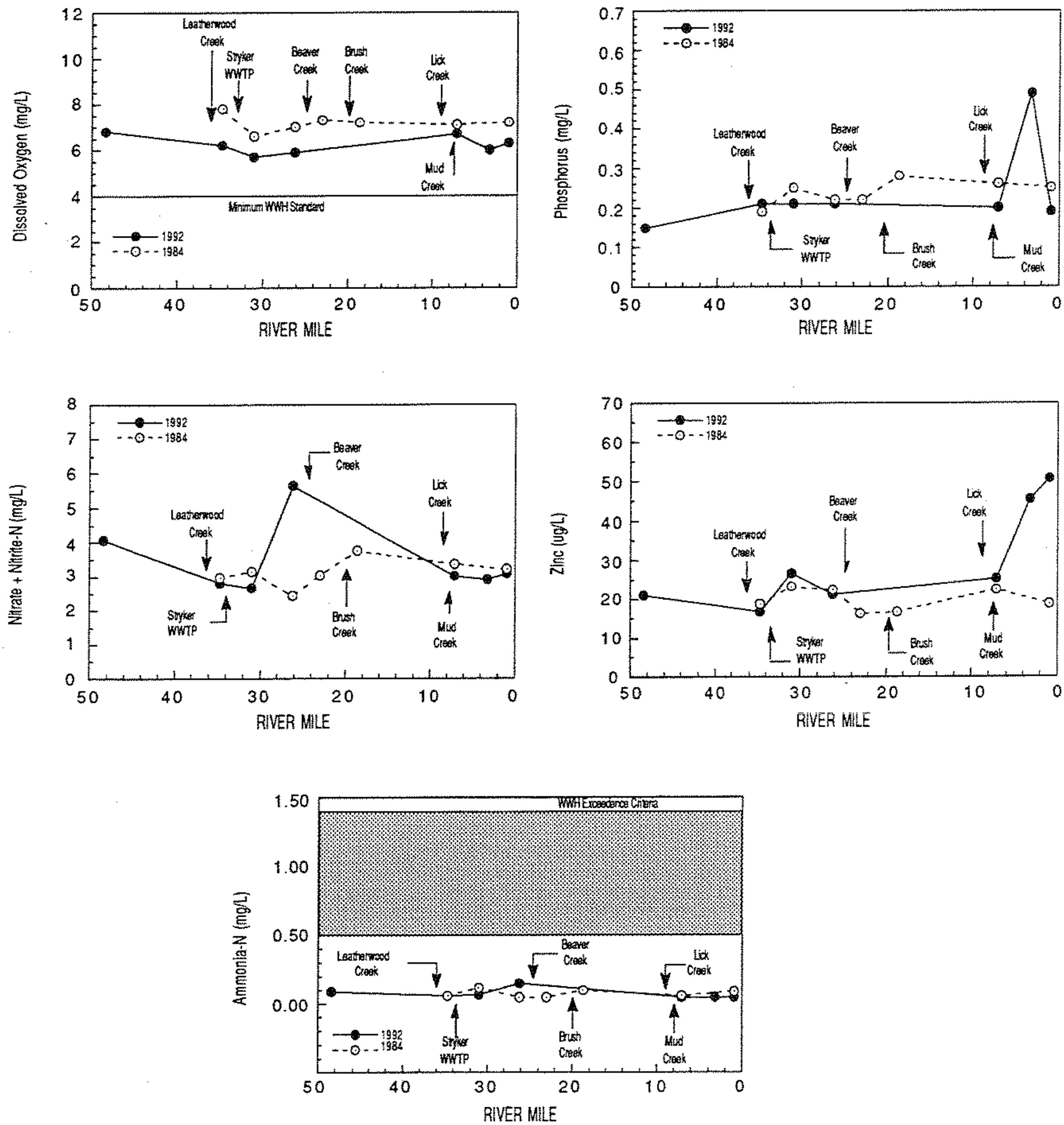


Figure 11. Longitudinal trend of mean dissolved oxygen, phosphorus, total nitrate-nitrite, zinc and ammonia in the Tiffin River, 1984 and 1992. Note: Shaded area in ammonia-N graph (bottom) denotes a range of minimum exceedence levels based on historical temperature and ph levels recorded from the mainstem.

Changes in Biological Community Performance: 1984 - 1992.

Fish Community

- The 1992 electrofishing results indicated significant improvements within the fish community of the Tiffin River in comparison with the results from an investigation conducted in 1984. Both community indices (IBI and MIwb) showed substantial increases and represented a shift from not achieving biocriteria throughout the study area in 1984 to partial achievement of biocriteria within the same reach in 1992 (Figure 12). Most notably, longitudinal performance as measured by the IBI exceeded or non significant departed from ecoregional expectations in 1992. In 1984, the IBI consistently performed below the WWH biological criteria. Modified Iwb values from 1992 showed a similar trend (significant improvement) in comparison to 1984 results; however, performance below ecoregional expectations was still observed. This resulted in partial attainment of WWH biological use criteria. Viewed in the aggregate (all stations), the reach between RM 35.4 and RM 1.1 supported greater species richness, a near 50% increase in relative abundance, and more sensitive species than in 1984. The significant improvement observed within the fish community appeared a result of both an increase in the quality and extent of macrohabitats (deadwood snags) and basin wide reductions of point and nonpoint pollutant loadings.

- The most significant modifications to the physical habitats of the Tiffin River were essentially completed by about 1910. Although some original modifications have been maintained over the years, large scale and systematic channelization have not been undertaken since the original channel work. Consequently, natural fluvial processes have resulted in **limited** restoration of some riverine habitat characteristics. Undoubtedly the most influential component of macrohabitats throughout the study area was the presence of relatively stable and flow constricting deadwood snags. These provided most of the functional habitats encountered during the 1992 sampling efforts. It appeared that channel maintenance activities (public and private) over the past eight years had not aggressively cleared the stream of **all** obstructions and instead removed only the significant obstructions (e.g., log jams) to flow. The selective removal of log jams would likely have left intact well entrenched and stable fallen timber and positively influenced local habitat heterogeneity.

- Additionally, efforts to encourage conservation oriented land management practices in the largely agricultural Tiffin River basin have increased since 1990. These activities have included the promotion of conservation tillage, a reduction in tillage intensity, and the establishment of riparian buffer and grass filter strips on smaller tributaries. These activities should reduce agricultural nonpoint loadings (nutrients and sediment) to the Tiffin River and improve physical habitat characteristics.

- The ADV/mile for the Tiffin River mainstem shows clear improvement from 1984 to 1992 in both fish community indices (Table 12). The ADV/mile values for the IBI were reduced from 23.6 in 1984 to 0.1 in 1992. Modified Index of Well-being ADV/mile statistics were reduced from 95.1 in 1984 to 18.8 in 1992.

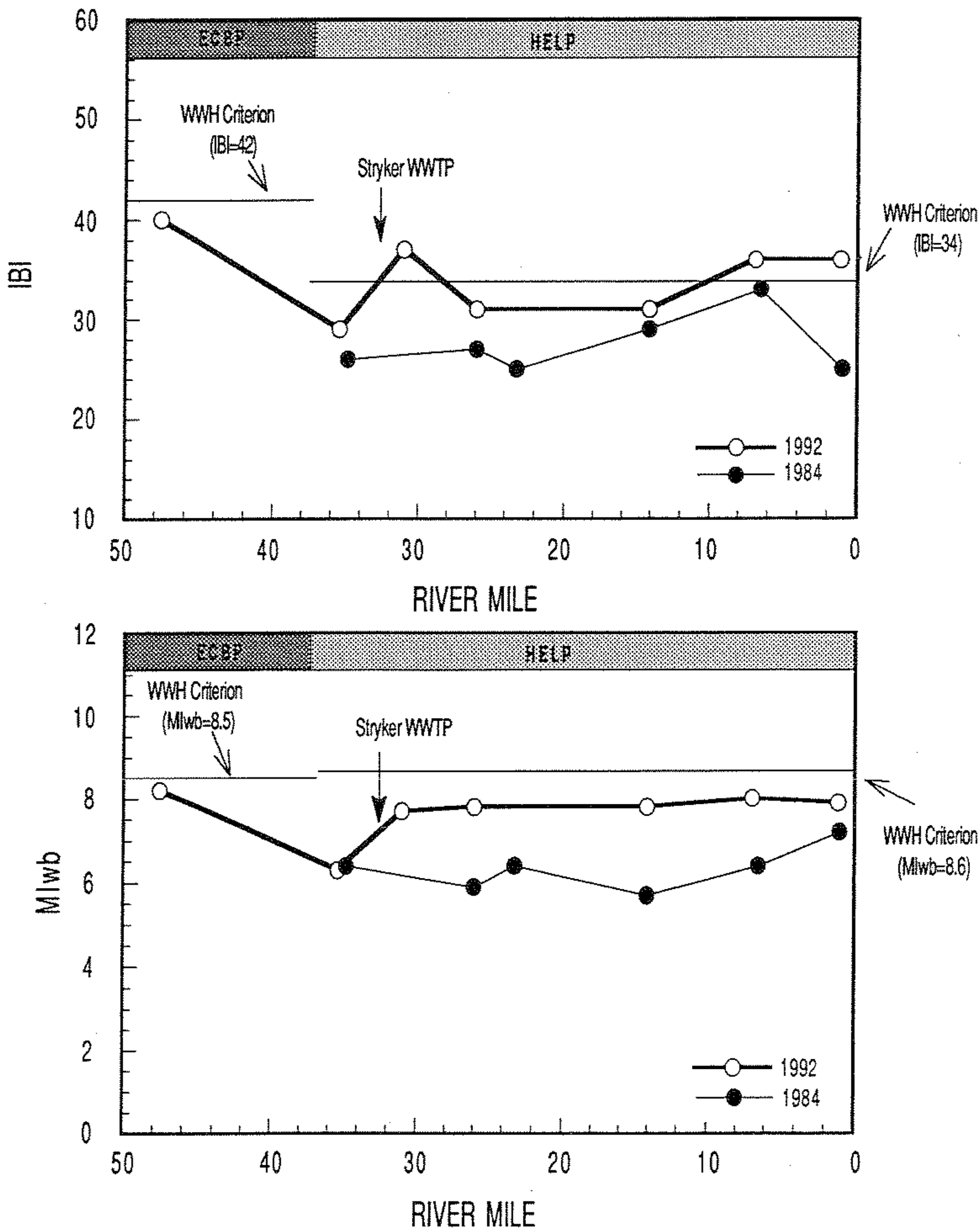


Figure 12. Longitudinal trend of the Index of Biotic Integrity (IBI; upper) and the Modified Index of Well-Being (MIwb; lower) in the Tiffin River, 1992 and 1984.

Macroinvertebrate Community

- Macroinvertebrate sampling indicated improved community condition throughout the length of the Tiffin River between 1984 and 1992 (Figure 13). In 1984, narrative evaluations based on the ICI were in the fair to good ranges at 6 of 7 stations. By comparison, ICI scores in 1992 ranged from marginally good to exceptional at the 6 quantitative stations and reflected minimal water quality impacts. Improvements were observed in both the quantitative (artificial substrate) and qualitative (natural substrate) samples; most sites exhibited increases in overall taxa richness, mayfly and caddisfly richness and abundance, and a general decrease in the predominance of less sensitive dipterans and other non-insect invertebrates.

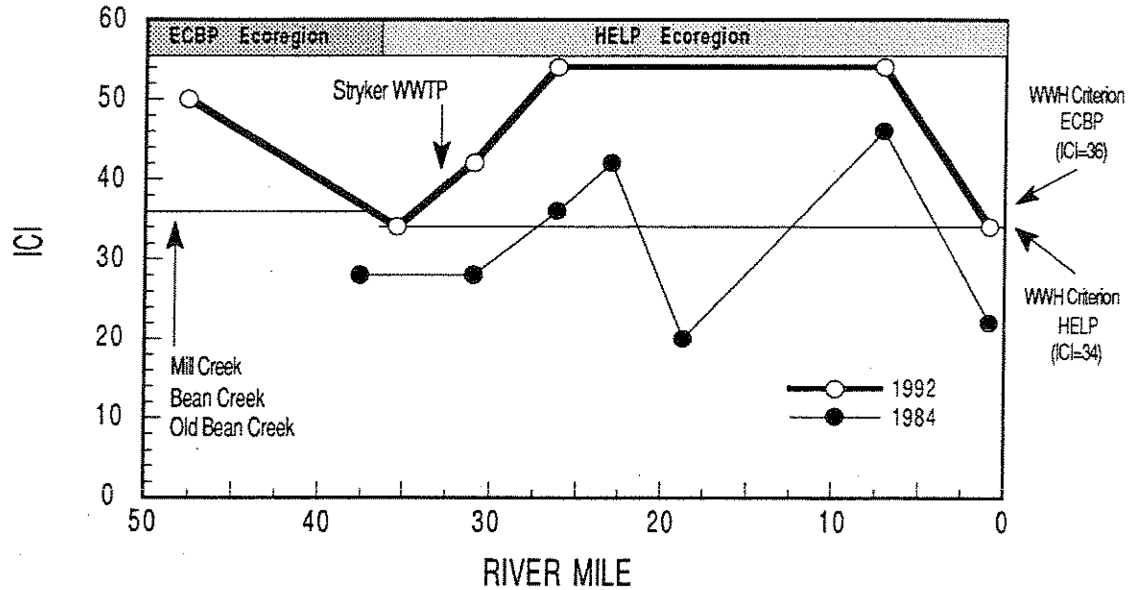


Figure 13. Longitudinal trend of the Invertebrate Community Index (ICI) in the Tiffin River, 1992 and 1984.

- One factor in the 1992 improvements may have been stronger currents associated with higher flows encountered during 1992 compared to 1984. This resulted in less extensive sedimentation in areas of strong current and more optimal habitat conditions. Areas of strong current were often associated with the presence of flow constricting deadwood snags or man-made structures such as bridge abutments and riprap. Communities from these habitats were generally in the good to exceptional ranges. In areas of sluggish current, ICIs from both sampling years generally scored in the fair or marginally good ranges. These samples were collected where velocities often fell below minimum requirements (0.3 feet/second) needed for direct interpretation of the ICI. Regardless of current velocities, ICIs collected under comparable habitat conditions were consistently higher in 1992 than in 1984 and were indicative of an improving trend in mainstem communities.

- The Tiffin River ADV/mile for the ICI dropped from 21.8 in 1984 to 0 in 1992 (Table 12). The change in statistics reflected the shift from mostly fair to good quality in 1984, to good and exceptional quality in 1991.

Table 12. Area of Degradation (ADV) statistics for **similar** sections of the Tiffin River mainstem study areas, 1984 and 1992. Values were calculated using ecoregion biocriteria as the level of background community performance.

	Biological Index Scores				ADV Statistics			Attainment Status (miles)			
Stream Index	Upper RM	Lower RM	Mini-mum	Maxi-mum	**ADV**	ADV/ Mile	Poor/VP ADV	FULL	PARTIAL	**NON**	Poor/VP
Tiffin River- (1984)											
IBI			25	33	**797**	23.6	0				
MIwb	34.8	0.9	5.7	7.2	**3215**	95.1	36	0.0	4.2	29.8	2.3
ICI			20	46	**655**	21.8	0				
Tiffin River- (1992)											
IBI			29	40	**3**	0.1	0				
MIwb	35.4	0.9	6.3	8.2	**645**	18.8	0	0.0	34.4	0.2	0.0
ICI			34	54	**0**	0.0	0				

References

Fausch, D.O., Karr, J.R. and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Trans. Amer. Fish. Soc. 113:39-55.

Gammon, J.R. 1976. The fish populations of the middle 340 km of the Wabash River. Tech. Report No. 86. Purdue University. Water Resources Research Center, West Lafayette, Indiana. 73 pp.

Gammon, J.R., A. Spacie, J.L. Hamelink, and R.L. Kaesler. 1981. Role of electrofishing in assessing environmental quality of the Wabash River. pp. 307-324. In: Ecological assessments of effluent impacts on communities of indigenous aquatic organisms. ASTM STP 703, J.M. Bates and C.I. Weber (eds.). Philadelphia, PA.

Hughes, R. M., D. P. Larsen, and J. M. Omernik. 1986. Regional reference sites: a method for assessing stream pollution. Env. Mgmt. 10(5): 629-635.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6 (6): 21-27.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Env. Mgmt. 5(1): 55-68.

Karr, J.R., K.D. Fausch, P.L. Angermier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Ill. Nat. Hist. Surv. Spec. Publ. 5. 28 pp.

Kelly, M. H., R. L. Hite. 1984. Evaluation of Illinois stream sediment data: 1974-1980. Illinois Environmental Protection Agency, Division of Water Pollution Control. Springfield, Illinois.

Ohio Department of Agriculure. 1992. State of Ohio Department of Agriculture, 1991 Annual Report and Agricultural Statistics.

Ohio Department of Natural Resources. 1954. Gazeteer or Ohio streams,

___ 1985. Principal streams and their drainage area. Division of Water. Ohio Department of Natural Resources. Columbus, Ohio.

___ 1960. Gazetteer of Ohio streams. Ohio Dept. Natural Resources, Division of Water, Ohio Water Plan Inventory Report No. 12.

___ 1978-1990. Division of Wildlife. Water pollution, fish kill, & stream litter investigations. Publication 7.

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

___ 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

___ 1988. Ohio Water Quality Standards (OAC 3745-1-11).

___ 1989. Ohio EPA manual of surveillance methods and quality assurance practices, updated edition. Division of Environmental Services, Columbus, Ohio.

___ 1989a. Addendum to biological criteria for the protection of aquatic life: Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

___ 1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning and Assessment, Columbus, Ohio.

___ 1989c. Ohio EPA policy for implementing chemical specific water quality based effluent limits and whole effluent toxicity controls in NPDES permits. Divisions of Water Pollution Control and Water Quality Planning and Assessment, Columbus, Ohio.

___ 1990. The cost of biological field monitoring. Division of Water Quality Planning and Assessment, Columbus, Ohio.

___ 1990a. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Division of Water Quality Planning and Assessment, Columbus, Ohio.

___ 1990b. State of Ohio nonpoint source assessment: Volume 5. Lake Erie West Region. Division of Water Quality Planning and Assessment, Nonpoint Source Program Management Section, Columbus, Ohio.

___ 1990c. Ohio water resource inventory - 1992 305b report. Volume II. Edward T. Rankin, editor. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

___ 1991. Calculation and uses of the Area of Degradation Value (ADV). Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

___ 1992. Ohio water resource inventory [305(b)].

Omernik, J. M. 1988. Ecoregions of the conterminous United States. Ann. Assoc. Amer. Geogr. 77(1): 118-125.

Omernik, J.M. and A.L. Gallant. 1988. Ecoregions of the upper midwest states. EPA/600/3-88/037. U. S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon. 56 pp.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus, Ohio.

Soil Conservation Service. 1990. Watershed Plan and Environmental Assessment for Upper Tiffin Watershed, Ohio and Michigan.

Soil Conservation Service. 1993. Communication.

Trautman, M. B. 1981 The fishes of Ohio with illustrated keys. Ohio State Univ. Press, Columbus. 782 p.

United States Department of Agriculture. 1985. Assessment and treatment of areas in Ohio impacted by abandoned mines. U.S. Dept. of Agriculture and Ohio Dept. of Natural Resources.

United States Department of the Interior-Geological Survey. 1981. Low flow characteristics of Ohio Streams. Open-File Report 81-1195.

___ 1984. Water resources data for Ohio. Volume 2. St. Lawrence Basin. Water-Data Report OH-84-2.

___ 1988. Ecoregions of the upper midwest states. EPA/600/3-88/037

___ 1992. Water resources data-Ohio. Volume 2. St. Lawrence Basin. Water-Data Report OH-92-2.

Wiederholm, T. (Ed.) 1983. Chironomidae of the Holarctic region. -- Keys and diagnoses. Part 1 Larvae. -- Ent. scand. Suppl. 19:1-457.

Williams County Soil and Water Conservation District. 1993. Communication. EPA/600/3-87/025. 66 pp.

Yoder, C.O., J. DeShon, R. Thoma, E. Rankin, and R. Beaumier. 1986. Evaluation of effluent toxicity screening of two selected discharges. Division of Water Quality Monitoring and Assessment, Columbus, Ohio.

Yoder, C.O. 1989. The development and use of biological criteria for Ohio surface waters. U.S. EPA, Criteria and Standards Div., Water Quality Stds. 21st Century, 1989: 139-146.

Appendix Tables

Appendix Table 1. A summary of pollutant discharges to the Tiffin River and its tributaries reported to the Ohio EPA Division of Emergency and Remedial Response and ODNR Wildlife from January 1978-December 1992.

Date	River/Creek	Entity	Township/City	Material	Amount	Units
TIFFIN RIVER			**Year: 78**			
09/19/78	Prairie Creek	Truck Accident		Milk	0	UNK
09/20/78	Tiffin River	Utilities		Oil	0	UNK
11/01/78	SPRING CR/DEER CR	FAYETTE STP	FAYETTE	MUNICIPAL SEWAGE	0	UNK
11/08/78	LICK CREEK	ARO CORPORATION	BRYAN	HYDROCHLORIC ACID	1,000	GAL
11/13/78	SCHMITZ DITCH	UNKNOWN	SWANTON	UNKNOWN	0	UNK
12/05/78	Prairie Creek Trib	George Isaac Co.		Oil	0	UNK
				Amount for Year:	1,000	GAL
			Year: 79			
04/29/79	TIFFIN RIVER TRIB	MATLACK	BRADY TWP	GASOLINE	1,750	GAL
				DIESEL FUEL	2,000	GAL
				COMBINED PRODUCT	0	
08/15/79	TIFFIN RIVER TRIB	STRYKER STP	STRYKER	SEWAGE	0	UNK
08/23/79	TIFFIN RIVER	CHEMICAL SOLVENTS	BRYAN	TRICHLORETHLYENE	200	GAL
09/18/79	Mill Creek Trib	REFINERS TRANSPORT	ALVORDTON	FERTILIZER 28-0-0	5,000	GAL
09/29/79	Mill Creek Trib	Refiners Transport (cont)	Alvordton	Fishkill	72,558	ITM
				Amount for Year:	8,950	GAL
			Year: 80			
04/18/80	TIFFIN RIVER	FERRO CORP	STRYKER	PLASTIC DUST AND ODOR	0	UNK
				Amount for Year:		GAL
			Year: 81			
01/27/81	BRUSH CREEK	NORFOLK & WESTERN RR	ECKLEY	METHYL ALCOHOL	15,000	GAL
02/18/81	BRUSH CREEK	PETTISVILLE STP	PETTISVILLE	SEWAGE	0	UNK

Appendix Table 1. (cont.).

Date	River/Creek	Entity	Township/City	Material	Amount	Units
			Year: 81			
04/04/81	TIFFIN RIVER	CEH CO	GERMAN TWP	PHOSPHORIC ACID	1,000	GAL
06/05/81	TIFFIN RIVER	STRYKER STP	STRYKER	SEWAGE	0	UNK
07/20/81	Lick Creek	Trucking		Fuel Oil	0	UNK
08/28/81	Mill Creek Trib	Gen. Farming	Gorham Twp	Hog manure	0	UNK
				Fishkill	83	ITM
				Amount for Year:	16,000	GAL
			Year: 82			
06/11/82	UNNAMED CREEK	LANDMARK CO	NOBLE TWP	FERTILIZER 28-0-0	1,000	GAL
07/19/82	Prairie Creek	UNK	Defiance Co	Fishkill	72	ITM
09/30/82	Mill Creek	Residence	Mill Cr Twp	Sewage/leach field	0	UNK
				Fishkill	68	ITM
10/18/82	TIFFIN RIVER	AMOCO OIL CO	STRYKER	ALACHLOR	700	GAL
				Amount for Year:	1,700	GAL
			Year: 83			
03/03/83	OWL CREEK TRIB	MR CHARLES ENGLER	RIDGEVILLE TWP	OIL	0	UNK
04/16/83	LICK CREEK	UNKNOWN	BRYAN	SEWAGE	0	UNK
04/18/83	TIFFIN RIVER	STRYKER STP	STRYKER	SEWAGE	0	UNK
08/16/83	DITCH 40 OUTLET	BRYAN STP	BRYAN	SEWAGE	0	UNK
09/07/83	PRAIRIE CREEK	BRYAN VILLAGE OF	WILLIAMS CO	WHITISH IN COLOR	0	UNK
09/15/83	TIFFIN RIVER	DEFIANCE FERTILIZER CO	DEFIANCE	UNKNOWN PRODUCT	0	UNK
				Amount for Year:		GAL
			Year: 84			
06/08/84	Mill Creek (Harrison Lake)	Camp Palmer STP	Gorham Twp	Sewage	0	UNK
				Fishkill	1,462	ITM
06/12/84	BRUSH CREEK	ZEHR & CO	ARCHBOLD	FERTILIZER 28-0-0	150	GAL
				Amount for Year:	150	GAL

Appendix Table 1. (cont.).

Date	River/Creek	Entity	Township/City	Material	Amount	Units
			Year: 85			
02/25/85	MILL CREEK TRIB	CROPMATE	ALVORDTON	FERTILIZER 28-0-0	0	UNK
				HERBICIDE	0	UNK
05/02/85	CHESTERFIELD DITCH	MR CHARLES RUPP	GORHAM TWP	PESTICIDE	0	UNK
				FISHKILL	21	ITM
05/16/85	BEAN CREEK TRIB	MR CHARLES RUPP	GORHAM TWP	PESTICIDE	0	UNK
				FISHKILL	0	UNK
06/07/85	DITCH	BLAST & METALURGICAL	FRANKLIN TWP	HYDROCHLORIC ACID	3	GAL
09/06/85	BLACK CREEK	NEY OIL CO	WASHINGTON TWP	GASOLINE	8,800	GAL
10/08/85	DEER CREEK	CITIZEN	GORHAM TWP	SEWAGE	0	UNK
				Amount for Year:	8,803	GAL
			Year: 86			
04/28/86	BRUSH CREEK TRIB	MR CLARENCE BRUNER	CLINTON TWP	FERTILIZER 28-0-0	600	GAL
				FERTILIZER 10-34-0	600	GAL
				FISHKILL	598	ITM
06/19/86	DRAINAGE DITCH	AGRI-MATE	ALVORDTON	FARM CHEMICALS	0	UNK
07/07/86	MILL CREEK TRIB	BEAL'S CROP MATE	ALVORDTON	Anhydrous Ammonia	0	UNK
				Liquid Nitrogen	0	UNK
				Fertilizer 10-34-0	0	UNK
				Phosphoric Acid	0	UNK
				Amount for Year:	1,200	GAL
			Year: 87			
05/14/87	OWL CREEK	UNKNOWN LAWN SERVICE	RIDGEVILLE	FISHKILL	458	ITM
				FARM CHEMICAL	0	UNK
08/03/87	DEER CREEK	FAYETTE STP	FAYETTE	SEWAGE	0	UNK
08/17/87	DITCH	MILLER BROTHERS PAVING	ARCHBOLD	FS-1 TACK COAT	3,000	GAL
09/10/87	Brush Creek	Public STP		Sewage	0	UNK
				Fishkill	75	ITM

Appendix Table 1. (cont.).

Date	River/Creek	Entity	Township/City	Material	Amount	Units
			Year: 87			
09/29/87	BUCKSKIN DITCH	PETRO-UNION INC	DEFIANCE	BRINE	0	UNK
10/11/87	TIFFIN RIVER TRIB	H R H INC	ARCHBOLD	MOTOR OIL	0	UNK
				Amount for Year:	3,000	GAL
			Year: 88			
06/08/88	BRUSH CREEK	WILLIAMS CO JAIL	ARCHBOLD	ODOR OF ROTTEN EGGS	0	UNK
				Wellwater high in H2S	0	UNK
				Fishkill	1,240	ITM
08/20/88	DITCH	LEASEWAY TRANSPORT	BRADY TWP	DIESEL FUEL	400	GAL
09/24/88	TIFFIN RIVER	STRYKER STP	SPRINGFIELD TWP	SEWAGE	0	UNK
11/09/88	STORM SEWER	SCHLEGEL CORP	WEST UNITY	METHOXY	0	UNK
				PROPENAL ACETATE	0	UNK
11/15/88	BRUSH CREEK TRIB	LAUB BROS OIL CO	ARCHBOLD	GASOLINE	0	UNK
				Amount for Year:	400	GAL
			Year: 89			
02/07/89	TIFFIN RIVER TRIB	LA CHOY FOODS CO	ARCHIBOLD	SODIUM HYPOCHLORATE	2,000	GAL
04/13/89	DRAINAGE DITCH	CARETTA TRUCKING	BRYAN	DIESEL FUEL	100	GAL
04/15/89	WALNUT RUN	WEST UNITY WTP	WEST UNITY	LAGOON DRUDGING	5,000	GAL
				Amount for Year:	7,100	GAL
			Year: 90			
01/04/90		MNS JUNKYARD	JEFFERSON	OIL	0	UNK
				LITTER	0	UNK
04/02/90	DITCH	MR OWEN SCHRADER	FARMER TWP	NITROGEN FERTILIZER	6,000	GAL
05/24/90	OLD BEAN CREEK	UNK	ROYALTON TWP	WHITE SUBSTANCE	0	UNK
06/11/90	DITCH	UNK	JEFFERSON	HYDROCHLORIC ACID 20	15	GAL
06/24/90	STORM SEWER	UNK	SPRINGFIELD TWP	PETROLEUM	0	UNK

Appendix Table 1. (cont.).

Date	River/Creek	Entity	Township/City	Material	Amount	Units
			Year: 90			
07/16/90	DITCH	STRABLE PAVING INC.	FARMER TWP	ASHPALT	230	GAL
08/02/90	UNKNOWN CREEK	UNK	ARCHBOLD	UNK	0	UNK
08/03/90	SEWER TO BRUSH CREEK	FROZEN SPECIALITY INC.	ARCHBOLD	ANHYDROUS AMMONIA	1,500	LBS
09/28/90	STORM SEWER	PHIL PONG	ARCHBOLD	DIESEL FUEL	20	GAL
11/18/90	POND	GENERAL TIRE	BRYAN	FUEL OIL #6	0	UNK
				SMOKE	0	UNK
11/29/90	FLAT RUN CREEK	BLISSFIELD TRUCK LINES	ARCHBOLD	OIL	10	GAL
				Amount for Year:	6,275	GAL
			Year: 91			
02/21/91	BEAN CREEK	QUALITY TUBES	FAYETTE	SEWAGE	0	UNK
04/05/91	DITCH	COUNTRYMARK / ARCHBOLD	FRANKLIN TWP	FERTILIZER 28-0-0	0	UNK
04/11/91	ROADSIDE DITCH	B P OIL CO/TIFFIN RIVERS	WEST UNITY	DIESEL FUEL	200	GAL
05/13/91	BEAN CREEK	MORENCI STP		RAW SEWAGE	250,000	GAL
08/05/91	DITCH	CONSOLIDATED RAIL CORP	STRYKER	LUBRICATING OIL	20,000	GAL
				CORN SYRUP	160,000	GAL
09/11/91	SANITARY SEWER	LACHOY / BEATRICE /	ARCHBOLD	50% SODIUM HYDROXIDE	300	GAL
09/16/91	SEWER TO BRUSH CR TRIB	SWAIN & SONS TRANSPORTS	ARCHBOLD	DIESEL FUEL	80	GAL
11/06/91	BRUSH CREEK TRIB	MILER BROTHERS EXCAVATING	GERMAN TWP	DIESEL FUEL	0	UNK
12/11/91	TIFFIN RIVER TRIB	STRYDEL INC	STRYKER	LUBRICATION OIL	50	GAL
				Amount for Year:	430,630	GAL
			Year: 92			
07/03/92		ROADWAY TRUCKING	GORHAM TWP	DIESEL FUEL	20	GAL
				Amount for Year:	20	GAL
				Total Known Spillage For Period:	485,228	GAL

Appendix Table 2. Ohio EPA values of the chemical/physical sampling results from the Tiffin River study area during July-September, 1992.

Mill Creek: RM 7.9 - Williams CR 22

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	1352	20.7	6.5	8.1	7.80	2.0	<1.0	NA
920728	1320	18.9	7.0	8.0	7.64	1.0	<1.0	NA
920812	1310	19.7	7.4	8.6	8.21	<1.0	<1.0	NA
920826	1310	22.9	9.9	8.6	8.36	<1.0	<1.0	NA
920917	1310	20.5	7.4	8.4	7.95	1.2	1.0	NA
920923	1315	13.5	8.7	8.1	7.72	2.6	1.2	36

Mill Creek: RM 1.8 - Old Angola Rd.

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	1330	23.4	6.9	7.8	8.10	5.1	2.0	NA
920728	1300	20.5	7.3	8.1	7.74	2.0	<1.0	NA
920812	1245	20.2	7.4	8.2	8.06	1.6	1.0	NA
920826	1250	21.9	8.2	8.5	8.22	<1.0	<1.0	NA
920917	1245	20.4	6.4	8.2	7.77	2.1	1.6	NA
920923	1255	16.2	8.3	8.1	7.92	4.0	1.7	26

Old Bean Creek: RM 1.8 - Old Angola Rd.

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	1310	20.4	4.9	7.9	7.63	2.0	1.1	NA
920728	1225	18.8	5.6	7.7	7.63	<1.0	<1.0	NA
920812	1215	19.7	6.0	8.2	7.91	1.1	<1.0	NA
920826	1220	22.7	6.1	8.1	7.76	1.3	<1.0	NA
920917	1210	19.6	5.6	8.1	7.76	1.5	1.0	NA
920923	1225	13.5	7.1	7.6	7.53	1.2	<1.0	24

Appendix Table 2. (cont.)

Bean Creek: RM 2.2 - Old Angola Rd.

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	1320	20.9	6.8	8.3	7.83	4.5	2.0	NA
920728	1235	19.2	7.8	8.1	8.06	1.0	<1.0	NA
920812	1230	19.2	9.0	8.2	8.27	3.7	2.1	NA
920826	1235	21.7	7.5	8.6	8.23	<1.0	<1.0	NA
920917	1225	19.5	7.6	8.6	8.10	1.4	1.0	NA
920923	1235	13.5	9.1	8.1	8.06	1.4	1.0	32

Tiffin River: RM 48.4 - Alt. U.S. 20

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	1240	21.4	5.9	8.3	7.74	5.7	2.0	NA
920728	1200	18.9	6.4	8.0	7.89	1.5	<1.0	NA
920812	1140	19.9	7.6	8.6	8.28	3.1	1.5	NA
920826	1205	23.3	7.1	8.5	8.28	<1.0	<1.0	NA
920917	1135	19.4	6.4	8.3	7.99	2.0	1.2	NA
920923	1200	14.1	7.3	7.5	NA	2.3	1.2	NA

Tiffin River: RM 35.3 - S.R. 191

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	1210	22.4	5.8	8.5	7.94	3.2	1.3	NA
920728	1130	20.3	5.7	8.1	7.85	1.5	<1.0	NA
920812	1110	21.7	6.5	8.2	7.86	2.2	1.6	NA
920826	1135	22.8	6.1	8.2	8.17	<1.0	<1.0	NA
920917	1105	20.0	6.4	8.2	7.94	1.7	1.0	NA
920923	1130	15.8	6.5	7.8	7.60	3.6	1.5	37

Appendix Table 2. (cont.)

Tiffin River: RM 31.0 - S.R. 2 / S.R 34

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	1150	22.4	4.9	8.6	8.00	1.8	1.0	NA
920728	1100	20.2	5.7	8.0	7.80	1.9	<1.0	NA
920812	1045	21.4	6.1	8.4	7.99	2.1	1.0	NA
920826	1110	22.7	6.1	8.4	8.20	<1.0	<1.0	NA
920917	1040	19.6	5.8	8.2	7.86	1.7	1.0	NA
920923	1100	16.1	5.8	7.6	7.64	4.7	2.4	31

Tiffin River: RM 26.2 - Williams C.R. C

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	1130	22.4	5.0	8.3	7.67	6.5	2.4	NA
920728	1045	19.9	5.8	8.0	7.65	1.3	<1.0	NA
920812	1020	21.8	6.0	8.1	8.08	1.9	1.0	NA
920826	1055	22.2	6.1	8.4	8.15	1.0	<1.0	NA
920917	1025	19.4	6.4	8.2	7.92	1.5	1.0	NA
920923	1043	15.8	6.1	7.6	7.59	3.6	1.7	55

Tiffin River: RM 7.1 - Evansport Rd.

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	1055	22.6	5.7	8.4	8.16	3.4	1.6	NA
920728	1005	20.2	8.6	8.1	7.79	1.4	<1.0	NA
920812	0945	21.2	6.4	8.3	8.15	1.5	<1.0	NA
920826	1015	22.1	6.5	8.4	8.15	<1.0	<1.0	NA
920917	0945	19.0	6.8	8.1	7.98	1.4	1.0	NA
920923	1023	16.1	6.5	7.8	7.62	3.8	1.8	38

Appendix Table 2. (cont.)

Tiffin River: RM 3.2 - Stever Rd.

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	1035	22.1	4.8	8.1	7.88	2.4	1.0	NA
920728	0945	19.9	6.4	7.8	7.86	1.5	<1.0	NA
920812	0925	21.2	6.1	8.1	8.13	1.4	<1.0	NA
920826	0955	22.0	6.1	8.2	8.20	<1.0	<1.0	NA
920917	0925	18.8	6.8	8.1	8.01	1.4	<1.0	NA
920923	0955	16.1	6.5	7.6	7.63	3.5	1.8	28

Tiffin River: RM 0.9 - Dey Rd.

Date	Time	Temp (°C)	D.O. (mg/L)	pH (field) (S.U.)	pH (lab) (S.U.)	BOD_5 (mg/L)	$cBOD_5$ (mg/L)	COD (mg/L)
920713	0955	22.9	6.1	7.9	7.86	2.1	1.3	NA
920728	0925	19.9	6.4	7.9	7.85	1.0	<1.0	NA
920812	0905	21.3	5.8	8.1	8.09	1.7	1.1	NA
920826	0940	22.4	6.1	8.2	8.19	1.5	<1.0	NA
920917	0910	18.8	6.8	8.0	7.93	1.5	<1.0	NA
920923	0937	16.4	6.4	7.6	7.71	3.7	1.8	30

Mill Creek: RM 7.9 - Williams C.R. 22

Date	Time	Conduct. (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	1352	658	2.59	0.09	<0.05	0.4	0.20	131
920728	1320	531	3.98	0.13	0.12	1.7	0.16	38
920812	1310	735	1.94	0.02	<0.05	1.0	0.30	12
920826	1310	690	0.57	<0.02	<0.05	0.7	0.16	5
920917	1310	733	1.40	0.02	<0.05	0.9	0.17	<5
920923	1315	513	2.30	0.10	0.13	1.2	0.18	43

Appendix Table 2. (cont.)

Mill Creek: RM 1.8 - Old Angola Rd.

Date	Time	Conduct. (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	1330	484	3.35	0.19	0.08	0.9	0.16	65
920728	1300	384	4.65	0.11	0.09	1.4	0.13	43
920812	1245	509	2.31	0.03	<0.05	0.9	0.08	7
920826	1250	557	0.97	<0.02	<0.05	0.7	0.10	6
920917	1245	490	NA	0.02	0.11	0.8	0.11	5
920923	1255	420	1.25	0.14	0.12	0.7	0.11	28

Old Bean Creek: RM 1.9 - Old Angola Rd.

Date	Time	Conduct. (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	1310	663	9.45	0.12	0.05	0.7	0.09	30
920728	1225	814	13.50	0.12	0.07	0.9	<0.05	18
920812	1215	760	4.61	0.10	0.22	0.9	0.15	22
920826	1220	660	2.03	0.08	0.09	0.8	0.08	26
920917	1210	785	5.79	0.08	0.18	0.9	0.10	22
920923	1225	782	10.50	0.08	0.11	1.0	0.14	28

Bean Creek: RM 2.2 - Old Angola Rd.

Date	Time	Conduct. (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	1320	528	11.60	0.29	0.16	1.6	0.32	293
920728	1235	563	3.94	0.07	0.05	1.0	0.12	82
920812	1230	759	1.64	0.03	<0.05	0.8	0.19	57
920826	1235	739	0.90	0.02	<0.05	0.6	0.07	24
920917	1225	666	1.77	0.02	<0.05	0.6	0.09	43
920923	1235	614	2.62	0.05	<0.05	0.7	0.13	66

Appendix Table 2. (cont.)

Tiffin River: RM 48.4 - Alt. U.S. 20

Date	Time	Conduct (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (m.g/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	1240	470	9.08	0.32	0.18	1.1	0.32	438
920728	1200	567	5.35	0.10	0.06	1.0	0.06	79
920812	1140	739	1.78	0.03	<0.05	0.9	0.16	44
920826	1205	666	0.80	0.02	<0.05	0.6	0.08	21
920917	1135	671	3.34	0.04	0.09	0.7	0.13	42
920923	1200	NA	NA	NA	NA	NA	NA	77

Tiffin River: RM 35.3 - S.R. 191

Date	Time	Conduct. (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	1210	574	1.82	0.12	0.07	0.4	0.24	167
920728	1130	513	5.68	0.13	0.05	0.9	0.18	66
920812	1110	693	1.92	0.04	<0.05	0.6	0.23	63
920826	1135	722	0.91	0.03	0.06	0.6	0.13	58
920917	1105	668	2.05	0.04	<0.05	NA	NA	54
920923	1130	461	4.56	0.10	0.05	1.0	0.25	105

Tiffin River: RM 31.0 - S.R. 2 / S.R. 34

Date	Time	Conduct. (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	1150	688	2.05	0.09	<0.05	0.4	0.21	170
920728	1100	948	5.04	0.14	<0.05	1.1	0.13	74
920812	1045	670	2.01	0.04	<0.05	0.6	0.26	108
920826	1110	713	0.90	0.02	0.09	0.6	0.14	74
920917	1040	627	1.98	0.05	<0.05	NA	NA	90
920923	1100	421	4.05	0.10	0.12	1.0	0.30	134

Appendix Table 2. (cont.)

Tiffin River: RM 26.2 - Williams C.R. C

Date	Time	Conduct. (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	1130	488	20.00	0.65	0.62	1.8	0.36	327
920728	1045	478	4.83	0.14	<0.05	1.1	0.13	60
920812	1020	667	2.22	0.03	<0.05	0.7	0.12	94
920826	1055	744	0.99	0.02	0.07	0.5	0.16	86
920917	1025	649	1.76	0.04	<0.05	NA	NA	5
920923	1043	397	3.96	0.09	<0,05	1.0	0.29	154

Tiffin River: RM 7.1 - Evansport Rd.

Date	Time	Conduct. (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	1055	628	3.70	0.16	<0.05	0.6	0.29	324
920728	1005	477	5.30	0.12	0.05	1.0	0.14	101
920812	0945	700	2.49	0.04	<0.05	1.0	0.19	104
920826	1015	740	0.92	<0.02	<0.05	0.6	0.16	94
920917	0945	679	2.65	0.04	<0.05	0.7	0.13	57
920923	1023	312	NA	0.08	<0.05	0.8	0.36	232

Tiffin River: RM 3.2 - Stever Rd.

Date	Time	Conduct. (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	1035	681	3.82	0.09	<0.05	0.4	0.18	86
920728	0945	473	5.27	0.12	0.05	0.8	0.50	144
920812	0925	689	2.48	0.04	<0.05	0.6	1.60	78
920826	0955	749	1.02	<0.02	<0.05	0.6	0.15	66
920917	0925	670	2.59	0.03	<0.05	0.6	0.13	5
920923	0955	308	2.28	0.12	<0.05	0.8	0.36	176

Appendix Table 2. (cont.)

Tiffin River: RM 0.9 - Dey Rd.

Date	Time	Conduct. (umhos/cm)	NO_3-NO_2 (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	T-P (mg/L)	T-Nflt Residue (mg/L)
920713	0955	638	4.40	0.11	<0.05	0.6	0.15	91
920728	0925	474	5.34	0.13	0.05	0.9	0.16	123
920812	0905	694	2.75	0.06	<0.05	0.7	0.16	75
920826	0940	768	0.99	<0.02	<0.05	0.5	0.12	34
920917	0910	662	2.60	0.04	<0.05	0.7	0.14	65
920923	0937	314	2.32	0.10	<0.05	0.8	0.39	254

Mill Creek: RM 7.9 - Willaims C.R. 22

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	1352	NA	<0.2	79	<30	<10	6310	2
920728	1320	NA	<0.2	85	<30	<10	2390	<2
920812	1310	NA	<0.2	104	<30	<10	857	<2
920826	1310	NA	<0.2	86	<30	<10	348	<2
920917	1310	NA	<0.2	102	<30	NA	568	<2
920923	1315	NA	<0.2	71	<30	<10	5750	<2

Mill Creek: RM 1.8 - Old Angola Rd.

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	1330	NA	<0.2	55	<30	<10	2500	<2
920728	1300	NA	<0.2	57	<30	<10	3410	<2
920812	1245	NA	<0.2	66	<30	<10	577	<2
920826	1250	NA	<0.2	70	<30	<10	379	<2
920917	1245	NA	<0.2	60	<30	NA	955	<2
920923	1255	NA	<0.2	53	<30	<10	3080	<2

Appendix Table 2. (cont.)

Old Bean Creek: RM 1.9 - Old Angola Rd.

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	1310	NA	<0.2	90	<30	<10	1540	<2
920728	1225	NA	<0.2	122	<30	<10	827	<2
920812	1215	NA	<0.2	107	<30	<10	1400	<2
920926	1220	NA	<0.2	92	<30	<10	1390	<2
920917	1210	NA	<0.2	92	<30	NA	1770	<2
920923	1225	NA	<0.2	114	<30	<10	1940	<2

Bean Creek: RM 2.2 - Old Angola Rd.

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	1320	NA	<0.2	74	<30	<10	11100	<2
920728	1235	NA	<0.2	89	<30	<10	2930	<2
920812	1230	NA	<0.2	97	<30	<10	1710	<2
920826	1235	NA	<0.2	97	<30	<10	909	<2
920917	1225	NA	<0.2	114	<30	NA	1340	<2
920923	1235	NA	<0.2	88	<30	<10	3410	<2

Tiffin River: RM 48.4 - Alt. U.S. 20

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	1240	NA	0.2	63	<30	<10	14900	8
920728	1200	NA	<0.2	84	<30	<10	3000	<2
920812	1140	NA	<0.2	94	<30	<10	1870	<2
920826	1205	NA	<0.2	89	<30	<10	813	<2
920917	1135	NA	<0.2	97	<30	NA	2120	<2
920923	1200	NA	<0.2	86	<30	<10	4410	<2

Appendix Table 2. (cont.)

Tiffin River: RM 35.3 - S.R. 191

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	1210	NA	<0.2	72	<30	<10	6730	4
920728	1130	NA	<0.2	75	<30	<10	2380	<2
920812	1110	NA	<0.2	96	<30	<10	3080	<2
920826	1135	NA	<0.2	92	<30	<10	2900	<2
920917	1105	NA	<0.2	95	<30	NA	3010	2
920923	1130	NA	<0.2	68	<30	<10	7860	2

Tiffin River: RM 31.0 - S.R. 2 / S.R. 34

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	1150	NA	<0.2	86	<30	<10	7050	3
920728	1100	NA	<0.2	71	<30	<10	3580	2
920812	1045	NA	<0.2	95	<30	<10	4560	<2
920826	1110	NA	<0.2	91	<30	<10	2930	<2
920917	1045	NA	<0.2	90	<30	<10	4460	2
920923	1100	NA	<0.2	61	<30	<10	9360	4

Tiffin River: RM 26.2 - Williams C.R. C

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	1130	NA	0.2	61	<30	<10	16100	8
920728	1045	NA	<0.2	70	<30	<10	3620	<2
920812	1020	NA	<0.2	92	<30	<10	4090	<2
920826	1055	NA	<0.2	95	<30	<10	3470	<2
920917	1025	NA	<0.2	94	<30	NA	2900	<2
920923	1043	NA	<0.2	57	<30	10	10900	4

Appendix Table 2. (cont.)

Tiffin River: RM 7.1 - Evansport Rd.

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	1055	NA	0.2	68	<30	<10	14000	7
920728	1005	NA	<0.2	70	<30	11	4170	2
920812	0945	NA	<0.2	92	<30	<10	4210	<2
920826	1015	NA	<0.2	92	<30	<10	3470	<2
920917	0945	NA	<0.2	94	<30	NA	2790	<2
920923	1023	NA	<0.2	45	<30	13	15400	5

Tiffin River: RM 3.2 - Stever Rd.

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	1035	NA	<0.2	68	<30	<10	4780	2
920728	0945	NA	<0.2	70	<30	13	4370	<2
920812	0925	NA	<0.2	93	<30	<10	3590	<2
920826	0955	NA	<0.2	92	<30	<10	2700	<2
920917	0925	NA	<0.2	95	<30	NA	3030	<2
920923	0955	NA	<0.2	44	<30	10	13500	6

Tiffin River: RM 0.9 - Dey Rd.

Date	Time	T-As (ug/L)	T-Cd (ug/L)	T-Ca (mg/L)	T-Cr (ug/L)	T-Cu (ug/L)	T-Fe (ug/L)	T-Pb (ug/L)
920713	0955	NA	<0.2	68	<30	<10	4990	<2
920728	0925	NA	<0.2	70	<30	11	4420	5
920812	0905	NA	<0.2	92	<30	<10	3580	<2
920826	0940	NA	<0.2	89	<30	<10	1630	<2
920917	0910	NA	<0.2	92	<30	NA	2990	<2
920923	0937	NA	<0.2	45	<30	<10	13500	6

Appendix Table 2. (cont.)

Mill Creek: RM 7.9 - Williams C.R. 22

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100 ml)
920713	1352	22	<40	45	288	>10000
920728	1320	19	<40	<10	290	NA
920812	1310	25	<40	<10	363	140
920826	1310	26	<40	<10	322	NA
920917	1310	24	<40	<10	354	140
920923	1315	16	43	18	243	NA

Mill Creek: RM 1.8 - Old Angola Rd.

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100 ml)
920713	1330	20	<40	<10	220	390
920728	1300	13	<40	12	196	NA
920812	1245	18	<40	13	239	470
920826	1250	22	<40	<10	265	NA
920917	1245	17	<40	<10	220	510
920923	1255	15	<40	12	194	NA

Old Bean Creek: RM 1.9 - Old Angola Rd.

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100 ml)
920713	1310	19	<40	16	303	3000
920728	1225	28	<40	<10	420	NA
920812	1215	25	<40	<10	370	140
920826	1220	23	<40	53	324	NA
920917	1210	24	NA	<10	329	620
920923	1225	26	<40	10	392	NA

Appendix Table 2. (cont.)

Bean Creek: RM 2.2 - Old Angola Rd.

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100 ml)
920713	1320	19	58	38	263	>10000
920728	1235	20	<40	11	305	NA
920812	1230	24	<40	25	341	230
920826	1235	26	<40	<10	349	NA
920917	1225	25	<40	46	388	720
920923	1235	21	<40	13	306	NA

Tiffin River: RM 48.4 - Alt. U.S. 20

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100 ml)
920713	1240	18	<40	56	231	>10000
920728	1200	19	<40	16	288	NA
920812	1140	24	<40	13	334	210
920826	1205	25	<40	<10	325	NA
920917	1135	24	<40	13	341	1200
920923	1200	21	<40	18	301	NA

Tiffin River: RM 35.3 - S.R. 191

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100 ml)
920713	1210	20	<40	17	262	4000
920728	1130	17	<40	10	257	NA
920812	1110	24	<40	11	339	480
920826	1135	26	<40	<10	337	NA
920917	1105	24	<40	20	336	650
920923	1130	17	<40	33	240	NA

Appendix Table 2. (cont.)

Tiffin River: RM 31.0 - S.R. 2 / S.R. 34

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100 ml)
920713	1150	24	<40	66	314	1000
920728	1100	16	<40	11	243	NA
920812	1045	24	<40	18	336	1000
920826	1110	26	<40	<10	334	NA
920917	1040	22	<40	16	315	770
920923	1100	16	<40	39	218	NA

Tiffin River: RM 26.2 - Williams C.R. C

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100 ml)
920713	1130	16	51	42	218	140
920728	1045	17	<40	12	245	NA
920812	1020	23	<40	12	324	430
920826	1055	26	<40	<10	344	NA
920917	1025	24	<40	11	334	600
920923	1043	15	<40	41	204	NA

Tiffin River: RM 7.1 - Evansport Rd.

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100 ml)
920713	1055	22	<40	51	260	2800
920728	1005	17	<40	13	245	NA
920812	0945	23	<40	15	324	250
920826	1015	27	<40	<10	341	NA
920917	0945	23	<40	<10	329	500
920923	1023	12	<40	53	162	NA

Appendix Table 2. (cont.)

Tiffin River: RM 3.2 - Stever Rd.

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100)
920713	1035	20	<40	32	252	490
920728	0945	17	42	162	245	NA
920812	0925	24	<40	12	331	150
920826	0955	26	<40	<10	337	NA
920917	0925	23	<40	<10	332	380
920923	0955	12	<40	47	159	NA

Tiffin River: RM 0.9 - Dey Rd.

Date	Time	T-Mg (mg/L)	T-Ni (ug/L)	T-Zn (ug/L)	Hardness (mg/L)	Fecal Coliform (#/100 ml)
920713	0955	21	<40	38	256	760
920728	0925	17	43	81	245	NA
920812	0905	23	<40	112	324	160
920826	0940	25	<40	<10	325	NA
920917	0910	23	<40	19	324	350
920923	0937	12	<40	44	162	NA