Biological and Water Quality Survey of Mill Creek and Selected Tributaries and Bokes Creek

(Logan, Union and Delaware Counties)

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Introduction

The Mill Creek study area extended from upstream of Cottonslash Rd. (RM 24.8) to upstream from the Mill Rd. bridge (RM 1.8) and included four small tributaries to Mill Creek: Town Run, Crosses Run, Blues Creek and the BMY tributary. One other small stream in close proximity to Mill Creek was also sampled during 1990: Bokes Creek. Sampling results from this stream were evaluated and incorporated into this report.

Specific objectives of this evaluation were to:

1) Continue to measure and evaluate instream biological and chemical water quality changes which may have occurred since the connection of the Ray Lewis & Sons discharge to the Marysville WWTP and revisions to the WWTP's NPDES permit..
2) Provide biological and chemical data on nonpoint source concerns in the basin and in Bokes Creek.
3) To further evaluate Crosses Run for sources of toxicants and biological degradation.
4) To evaluate the Marysville WWTP and BMY Corporation impacts on their respective receiving streams.
5) To compare results of previous surveys in 1978 and 1986 to determine trends.

The findings of this evaluation may factor into regulatory actions taken by Ohio EPA (e.g. NPDES permits) and eventually be incorporated into the State water quality management plans and the biennial 305(b) report.

Based on the results of the 1990 monitoring effort, the following summary, conclusions and recommendations are made for the Mill Creek and Bokes Creek Basins.

Summary

Results from the 1990 survey of the Mill Creek basin roughly paralleled the findings from the 1986 survey (Ohio EPA 1987a). However the total number of stream miles documented as biologically impaired has increased since 1986 (Tables 1 and 16, Figures 11 and 13). The number of river miles fully attaining the WWH aquatic life use designation in 1986 was 6.1 with another 11.3 miles partially attaining criteria and 6.0 miles not attaining. In contrast, in 1990 only 1.9 river miles fully attained the WWH use with approximately the same number of miles partially meeting criteria (11.6 miles) as in 1986. The telling difference is in the increase in number of miles not meeting criteria, up to 9.6 miles in 1990. ADV statistics indicated an increase in MIwb and IBI based values (645 to 945, and 577 to 646) between 1986 and 1990. ADV based on the ICI showed a modest decline (936 to 709) in the same period.

Biological community composition and instream chemical sampling results suggested a problem with CSOs and organic enrichment upstream from Town Run. Downstream from the confluence there were also indications of toxic influences. A potential source for this toxicity is contaminated casting sands and leachate/runoff entering Mill Creek via Town Run from the closed Eljer Plumbing Facility. In 1990 sediment concentrations of copper, lead, zinc and cadmium continued to remain elevated to extremely elevated in Mill Creek between North Main St. (RM 19.0) and Cherry St. (RM 18.1). Biological indications of organic enrichment and toxic influences were found in this segment and downstream from the Marysville WWTP. This problem persisted in 1990 despite Ray Lewis and Sons, a major metals finishing facility identified in the 1986 report as a problem, connecting all pretreated wastewaters to the Marysville WWTP. Possible sources of these contaminants in addition to Ray Lewis and Sons include: storm water runoff, backwash or settling pond discharges from the Marysville Water Treatment Plant, the previously mentioned contaminated casting sands, inplace contaminants, the flow tiered permit at the Marysville WWTP which allows discharge of higher amounts of metals, and/or some as yet unknown source. Additionally, elevated fecal coliform counts in this same reach suggest an ongoing problem with combined sewer discharges. An overflow point downstream from the Main St. bridge has since been capped and this problem may have diminished.

Although no PCBs were discovered in study area sediment samples, highly elevated levels of DDT and it metabolites were measured at Cherry St. (RM 18.1) downstream from the Marysville WWTP (Table 8). Endosulfan sulfate, a metabolic byproduct of endosulfan - a pesticide used for a wide variety of crops, was detected in samples from Cherry St. downstream to Crosses Run. Comparable concentrations of endosulfan sulfate were also detected in Crosses Run. Heptachlor and dieldrin were measured at the highly to extremely elevated level in Crosses Run downstream from the O. M. Scott facility (RM 0.8). The only other location in the study area where dieldrin was detected was the first site downstream from the confluence with Crosses Run. Further sampling is needed to more accurately delineate the source, severity and extent of these problems.

Long-term monitoring of Mill Creek at Cherry St.(RM 18.1) has revealed improving trends for dissolved oxygen, biochemical oxygen demand (BOD) and ammonia (Figures 7 and 8) that coincide with the development of advanced wastewater treatment at the Marysville WWTP. Nitrates, however, have increased gradually through the same period, although reductions have been documented since 1988 coinciding with the upgrade at the Marysville WWTP (Figure 11). Maximum water column concentrations of zinc and lead have shown substantial declines between 1977 and 1990.

The improved chemical water quality at RM 18.1 have not resulted in the improvements expected in the instream biological communities downstream. Macroinvertebrates closely reflected the trends documented in 1986. The fish community revealed a lessened impact immediately downstream from the Marysville WWTP, but otherwise followed trends documented in 1978 with some improvement in species richness in the vicinity of Crosses Run.

Crosses Run historically has impacted the water resource quality of Mill Creek and continues to prevent full attainment of WQS criteria, interrupting recovery from the impacts of the Marysville WWTP. The macroinvertebrate communities were impacted more severely than the fish communities in 1990 with the ICI dropping into the fair range. This resulted in non-attainment of the WWH ICI criterion. The macroinvertebrate community response patterns in 1990 were not strongly indicative of toxic impacts and may indicate additional nutrient enrichment. Biological sampling results in Crosses Run at RM 0.8 showed little improvement over the poor and very poor conditions measured in 1986. Macroinvertebrates collected 0.7 miles downstream, however, did reach the fair range prior to entering Mill Creek.

Remaining downstream sites in both surveys exceeded the macroinvertebrate WWH ICI criterion. However, recovery was considered incomplete, indicative of significant organic enrichment and not comparable to the high quality communities observed upstream from Marysville.

Since 1988 the Ohio EPA has observed substantial improvements in biological community performance downstream from WWTP discharges in numerous Ohio rivers and streams. The results observed in Mill Creek between 1978, 1986, and 1990 are a conspicuous exception to this observation. This is best portrayed by ADV statistics (Table 15) which show only modest improvements in the macroinvertebrate results between 1986 and 1990. The fish community results show an *increase* in the ADV (higher ADVs = poorer community performance; see p. 18) for both the IBI and MIwb between 1986 and 1990. This indicates that despite improvements in the discharge of conventional parameters from the Marysville WWTP that other parameters (e.g. metals, pesticides and organic chemicals) and sources (Town Run, CSOs, O.M. Scott, etc.) are still continuing to cause significant impairment in Mill Creek and its' tributaries.

Bokes Creek, despite the presence of adequate instream and riparian habitat, yielded aquatic communities that either partially or did not attain WWH criteria. Based on biological response and instream water chemistry the apparent cause of stress was nutrient enrichment from both point and nonpoint sources of pollution.

Conclusions

√ Despite major upgrades of the Marysville Waste Water Treatment Plant, the capping of the majority of the combined sewer overflows in the system and the implementation of a pretreatment program, the 1990 biological sampling results revealed little improvement since 1986. In fact, the length of stream documented as not meeting the Warmwater Habitat aquatic life use designation criteria has increased from 6.0 to 9.6 miles between and 1990. Despite improved treatment technology, loadings for substances (i.e. BOD, ammonia and metals) *increased* between 1986 and 1990.

√ A trend of gradual decline in biological community scores upstream from Marysville (RM 24.8) suggests that, in conjunction with existing land uses, increased development in the headwaters of the basin is contributing to a decline in water resource quality. The sources and extent of this decline should be investigated further.

√ Upstream from Town Run in Marysville biological community composition and instream chemical sampling results documented an ongoing problem with CSOs and organic enrichment. (The Maple St. CSO thought to be responsible has since been capped since this survey; this problem may have diminished.) Downstream from Town Run indications of toxicity included further declines in the biological communities and sediment samples with elevated to extremely elevated concentrations of copper, lead and zinc. Macroinvertebrate sampling results in Town Run confirmed that it was severely degraded with strong indications of toxicity.

√ All sediment samples analyzed in the study area had elevated concentrations of heavy metals revealing in-place contaminants as a pervasive problem in the basin needing further delineation.

√ All sediment samples analyzed had detectable levels of organic contaminants. Contaminants found included heptachlor, aldrin, dieldrin, endosulfan, endosulfan sulfate, DDT and its metabolites. Highest concentrations for most compounds were found downstream from the Marysville WWTP and at the downstream site on Crosses Run. In Mill Creek concentrations decreased with downstream distance to the first site downstream from Crosses Run. Runoff, leachate and groundwater contamination from the landfill the Marysville WWTP is built on is the probable source of this contamination. Recent investigations by the USEPA have revealed the presence of a variety of pesticides, PCBs, volatile and semi-volatile organic compounds in this landfill. Effluent from the Marysville WWTP should not be discounted as another potential source. In Crosses Run, the location of sampling sites and sampling results suggest that the majority of the contamination measured at the downstream site is being delivered by the unnamed tributary flowing past the O.M. Scott treatment lagoons. The severity of contamination in this basin and the inability to fully document the source and extent of this problem warrant an in-depth study and a plan for remediation.

√ Long-term trend monitoring at Cherry St., downstream from the Marysville WWTP, has revealed improving trends for dissolved oxygen, biochemical oxygen demand (BOD) and ammonia that coincide with the upgrade to advanced wastewater treatment at the Marysville WWTP. Water column concentrations of zinc and lead have also declined. These results, however, were not paralleled by the biological results.

√ Macroinvertebrate communities in the stream segment between the WWTP and Crosses Run have revealed little change since 1986 despite the treatment improvements at the Marysville WWTP. Fish communities fairly closely followed the patterns documented in 1978, however, community scores revealed that the immediate impact associated with the Marysville WWTP was intermediate between those documented in 1978 and 1990. Some improvement in species richness was noted in the vicinity of Crosses Run.

√ Biological communities in Crosses Run have shown little or no improvement since 1986. The fish communities were evaluated as very poor to poor. Macroinvertebrate communities were poor to fair. Community response signatures reflected stresses associated with nutrient enrichment and toxics.

√ Downstream from Crosses Run biological communities, although improving with downstream distance, never attained their full potential based on upstream performance and available riparian and instream habitat. Performance in this segment was not significantly improved from previous surveys despite the improvement in most parameters measured at the Marysville WWTP. O.M. Scott and possibly the Goodyear Corp. and BMY Corp. contributed to this impact.

Recommendations

Evaluation of Designated Aquatic Life Uses

Mill Creek - Full attainment of the Warmwater Habitat (WWH) aquatic life use designation was achieved only at the first site upstream from the confluence with the Scioto River (Table 1). Historically attainment of the WWH criteria was also found at the upstream sites (RM 28.2 & 24.8). In 1990 fish community results at this site dropped to levels just below the WWH criteria. Despite this decline, biological sampling results in Mill Creek have demonstrated the ability to support WWH aquatic communities.

An in-depth evaluation of the riparian and instream habitat of Mill Creek revealed habitat characteristics that would easily support the WWH use designation (Table 11). QHEI values ranged from 58.5-77.0 (Mean = 66.3) and the ratio of MWH/WWH attributes was very low. Thus, the current WWH use designation is appropriate and should be retained.

Crosses Run - This stream is currently designated in the Ohio Water Quality Standards as WWH. The biological communities sampled in 1986 and 1990 revealed severe impairment. The fish communities were more severely impacted than the macroinvertebrate communities with neither taxonomic group achieving their respective WWH criteria. Fish communities reflected very poor to poor conditions instream. Although some riparian and instream habitat disruption was evident at upstream sampling sites, the downstream portions had habitat characteristics capable of supporting the existing WWH use. Crosses Run has not been petitioned under the Ohio Ditch Law, the Union Co. Engineers Office has no records of the stream being channelized, and the disruption of habitat was not an extensive and irretrievable anthropogenic modification. Therefore the criteria for designating as less than WWH were not met. The WWH use designation is appropriate and should be retained. Replanting the wooded riparian buffer along the water course in the upper portions of the basin would permit, via natural recovery processes, the elimination of the few Modified Warmwater Habitat attributes present in this area.

Blues Creek- Currently designated as WWH, this stream is impacted by habitat alterations and nonpoint source runoff in its headwaters. Downstream portions, however, have more natural habitat features and were judged to be physically capable of supporting a WWH aquatic community. This judgement was reinforced by the presence of aquatic communities that met or exceeded the WWH aquatic life use criteria in 1990. The existing aquatic life use designation is therefore appropriate for the downstream portions. However, Blues Creek is a petitioned ditch from west of SR 4 (RM 11.85) to its headwaters (W. Galloway, Union County Engineers Office, personal communication). Inspection of the 7 1/2 minute topographic maps reveal characteristics of an extensively channelized habitat. Due to the recurring disruption of the physical habitat that the ditch maintenance will entail, the more appropriate aquatic life use designation for this segment would be Modified Warmwater Habitat (MWH).

Bokes Creek - The existing WWH aquatic life use is considered appropriate. Although the majority of sites sampled partially achieved WWH criteria with the upstream site not achieving criteria nutrient enrichment associated with both point and nonpoint sources of pollution were the cause of the partial and non-attainment of criteria. Exceedences of the fecal coliform, nitrate, dissolved oxygen and ammonia WQS criteria were documented at various sites throughout the basin. An in-depth evaluation of the riparian and instream habitat of Bokes Creek revealed habitat characteristics that would easily support the WWH use designation with the mean QHEI score of 67 (Table 11).

BMY Tributary - This small undesignated stream has a drainage area of less than three square miles. It was originally channelized in the mid to late 1920s and was rechannelized by private landowners within the last ten years (W. Galloway, Union County Engineers Office, personal communication). The small drainage area of this stream in concert with the observed extensive habitat modifications and the very low QHEI (27) suggest that the appropriate aquatic life use designation for this stream would be Limited Resource Water (LRW).

Table 1. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in Mill Creek and selected tributaries and Blues and Bokes Creek based on data collected during July-September 1990.

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	WWH Attainment Status[c]	Comments
Mill Creek						
24.8/28.2	44	7.7*	42	58.5	PARTIAL	Ust. Marysville
19.0/19.0	38^{ns}	6.2*	22*	63.0	PARTIAL	Ust. Town Run
18.8/18.6	33*	6.1*	18*	64.5	NON	Dst. Town Run
18.2/18.2	39^{ns}	8.4	12*	NA	**	Marys. WWTP Mix Zone
18.1/18.1	39^{ns}	7.5*	14*	66.0	PARTIAL	Dst. Marys. WWTP
18.0/ -	31^{*}	5.6*		68.0	(NON)	Dst. Marys. WWTP
17.0/16.9	28*	5.3*	20*	59.0	NON	Gugels Property
12.2/12.1	32*	7.5*	34^{ns}	76.5	PARTIAL	Ust. Crosses Run
11.7/11.7	34*	7.4*	26*	68.0	NON	Dst. Crosses Run
6.9/ 6.9	36^{ns}	7.6*	36	77.0	PARTIAL	Ust. Blues Creek
1.8/ 1.6	38^{ns}	8.6	40	71.5	FULL	USGS Gage nr. mouth
Town Run						
/ 0.1	-	-	P	NA	(NON)	@ mouth
Crosses Run						
2.1/ 2.0	15*	-	4*	34.5	NON	
0.8/ 0.1	21*	-	22*	62.0	NON	Dst. OM Scott
BMY Tributary						
3.4/ -	12*	-		-	NON	Ust. BMY
3.3/ 3.3	16*	-	P	-	NON	Dst. BMY
2.4 / 2.4	12*	-	P	27	NON	@ U.S. 33 rest area
Blues Creek						
6.7/ 6.2	30*	6.2*	F	49.5	NON	Recovering channelized
0.7/ 0.6	40^{ns}	8.1^{ns}	G	66.5	FULL	Dst. Ostrander
Bokes Creek						
27.2/27.5	28*	7.5*	30*	61.0	NON	Dst. W. Mansfield WWTP
21.3/21.4	32*	6.6*	42	58.5	PARTIAL	Dst. Terra International
13.2/14.8	32*	6.3*	38	82.5	PARTIAL	Dst. Egg Farms
5.6/ 5.6	36^{ns}	5.6*	36	66.0	PARTIAL	Downstream site

(Continued)

Table 1. Continued

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* significant departure from ecoregion biocriteria; poor and very poor results are underlined.

** Attainment status not applied to mixing zones.

ns Nonsignificant departure from ecoregion biocriteria (4 IBI or ICI units; 0.5 Iwb units).

a Narrative evaluation is used in lieu of ICI for qualitative samples (G=Good, MG=Marginally good, P=Poor).

b Qualitative Habitat Evaluation Index (QHEI) values based on the most recent version (Rankin 1989).

c Use attainment status based on one organism group is parenthetically expressed.

Ecoregion Biocriteria: Eastern Corn Belt Plains (ECBP)

INDEX - Site Type	WWH	EWH	MWH[d]
IBI - Headwaters/Wading	40	50	24
Mod. Iwb - Wading	8.3	9.4	5.8
ICI	36	46	22

[d] - Modified Warmwater Habitat for channel modifications.

Discharger Status

√ The O.M. Scott facility should be put on the major discharger list due to the significant impact on Crosses Run and Mill Creek and the documented significant risk for the release of toxic substances.

Future Monitoring Needs

√ ***Study Area*** - The next survey of the Mill Creek basin needs to extend further upstream to include the headwaters and Otter Creek. The development of the upper watershed associated with satellite manufacturing facilities servicing the East Liberty and Marysville Honda Manufacturing Plants and the attendant residential development, coupled with agricultural nonpoint source pollution, have resulted in measurable impacts to the biological communities at the upstream site (RM 24.8). This trend needs to be monitored.

√ ***Crosses Run*** - The multitude of impacts documented in Crosses Run warrant an in-depth investigation to determine the sources and causes. This should include determining which outfalls are contributing elevated heavy metals, which outfalls are causing extremely elevated levels of organic pesticides in the sediments, the source of the ammonia violations measured instream, the relative contribution of O.M. Scott and the Goodyear Corp. to the measured impacts, the influence of runoff from O.M. Scott test plots on WQS violations or other measurable impacts, and the extent of in-place contamination.

√ ***Bokes Creek*** - Instream biological impacts were documented at all sites sampled. Determination of specific sources was not possible due to the small number of sites and high flow during the sampling period which masked the relative contribution of human and animal related NPS impacts. Accurate mapping of land use and livestock waste land application patterns and rates during the load allocation study scheduled for 1992 should help to resolve these issues.

√ ***Sediment sampling*** - Further sediment sampling of the Mill Creek basin needs to be conducted and analyzed prior to the issuance of any new or revised permits. The organic chemical sediment sampling, although limited, did reveal significant problems downstream from the Marysville WWTP, Town Run, the closed Marysville Landfill, and the O.M. Scott facility. Metals were elevated throughout the basin and may be associated with closed landfills, active and closed industrial sources, and the Marysville WWTP. A more extensive sediment sampling regime needs to be conducted to delimitate the extent and severity of the contamination and to identify the source(s) of these chemicals.

√ ***Elevated ammonia concentrations*** - Elevated ammonia loadings in the Marysville WWTP effluent may indicate problems with incomplete nitrification at the WWTP. An evaluation of this problem should be undertaken. This could be a result of influent water containing metals or other compounds that are adversely affecting the biological treatment process at the WWTP.

√ ***Bioassays*** - Although the Marysville WWTP effluent was not acutely toxic when sampled on September 10, 1990, acute toxicity was documented in 1978 and 1986. Recently, however, additional industries have tied into the WWTP through the pretreatment program. This necessitates the need for periodic re-testing to assure the continued absence of acute toxicity. Additionally, the instream biological sampling results, particularly the macroinvertebrate sampling results, suggest a mix of nutrient enrichment and toxicity in the Marysville WWTP mixing zone. Therefore, periodic re-testing of the Marysville WWTP effluent *including chronic tests* should be conducted to prevent further deterioration of instream conditions.

Acute toxicity was documented in the effluent of the BMY Wheeled Vehicles outfall 001 with instream chronic toxicity predicted. More definitive bioassays should be conducted to better determine the magnitude of the acute toxicity associated with this effluent and its potential impact on Mill Creek.

√ ***Monthly Monitoring*** - the trend of increase in certain parameters necessitates the continuance of monthly monitoring at the Cherry Street ambient monitoring station. Quarterly sediment samples for both heavy metals and organochlorine pesticides should be included.

√ ***Comprehensive monitoring*** - Despite the implementation of increased point source controls in the Mill Creek basin resulting from recommendations developed in the 1986 intensive survey report, instream biological communities have not improved and in fact have declined. The 1990 survey has revealed, without identifying sources and magnitudes, additional problems within the basin including sediment organic and metals contamination. To properly address all of the water quality problems in the Mill Creek basin we need to draw on all the resources available within the agency involving other divisions (i.e. DERR and DWPC) that may be able to conduct additional sampling or have information that will help solve these problems.

Study Area Description

The study area is located in parts of the following three central Ohio counties: Logan, Union and Delaware (Figure 1). Principal subbasins in the study area include: Mill Creek and Bokes Creek. The drainage area of the combined subbasins covers 269.7 square miles (ODNR, 1960; 1985). Table 2 presents the general characteristics of the streams in the study area. The streams flow northwest to southeast discharging into the Scioto River upstream from the O'Shaughnessy Reservoir headwaters.

The study area is situated in the Eastern Corn Belt Plains ecoregion which is a region of extensive cropland agriculture. The gently rolling glacial till plain comprising the ecoregion is broken by moraines, kames and outwash plains. The ecoregion is almost entirely comprised of farmland.

Three-fourths of the area is cropland; the remainder is either permanent pasture, small woodlots, or urban.

The agricultural economy of the area has had a pronounced influence on stream water quality. Poor soil drainage has led to extensive stream channelization to assist artificial field drainage systems. Both surface runoff and field drain discharges can carry significant amounts of fertilizers, herbicides and insecticides to the waterbodies in this ecoregion (U.S. EPA, 1988; Ohio EPA, 1990).

Table 3 lists the location and type of sampling conducted in the study area during 1990.

Table 2. Stream Characteristics and Identified Pollution Sources in the Upper Scioto River Study Area

Stream Name	Length (Miles)	Avg Fall (Feet/Mile)	Drainage Area (Square Miles)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Mill Creek	37.8	6.2	185.5	Agriculture, Hydromodification, On-site Wastewater Treatment, In-place Pollutants	Marysville WWTP
Blues Creek	12.5	5.9	36.62	Agriculture, Hydromodification, In-place Pollutants	--
Crosses Run	1.9	1.6	5.24	Agriculture, Hydromodification, In-place Pollutants	O.M. Scott
Bokes Creek	28.1	6.3	84.2	Agriculture, Hydromodification, On-site Wastewater Treatment, Animal Husbandry	Egg farms

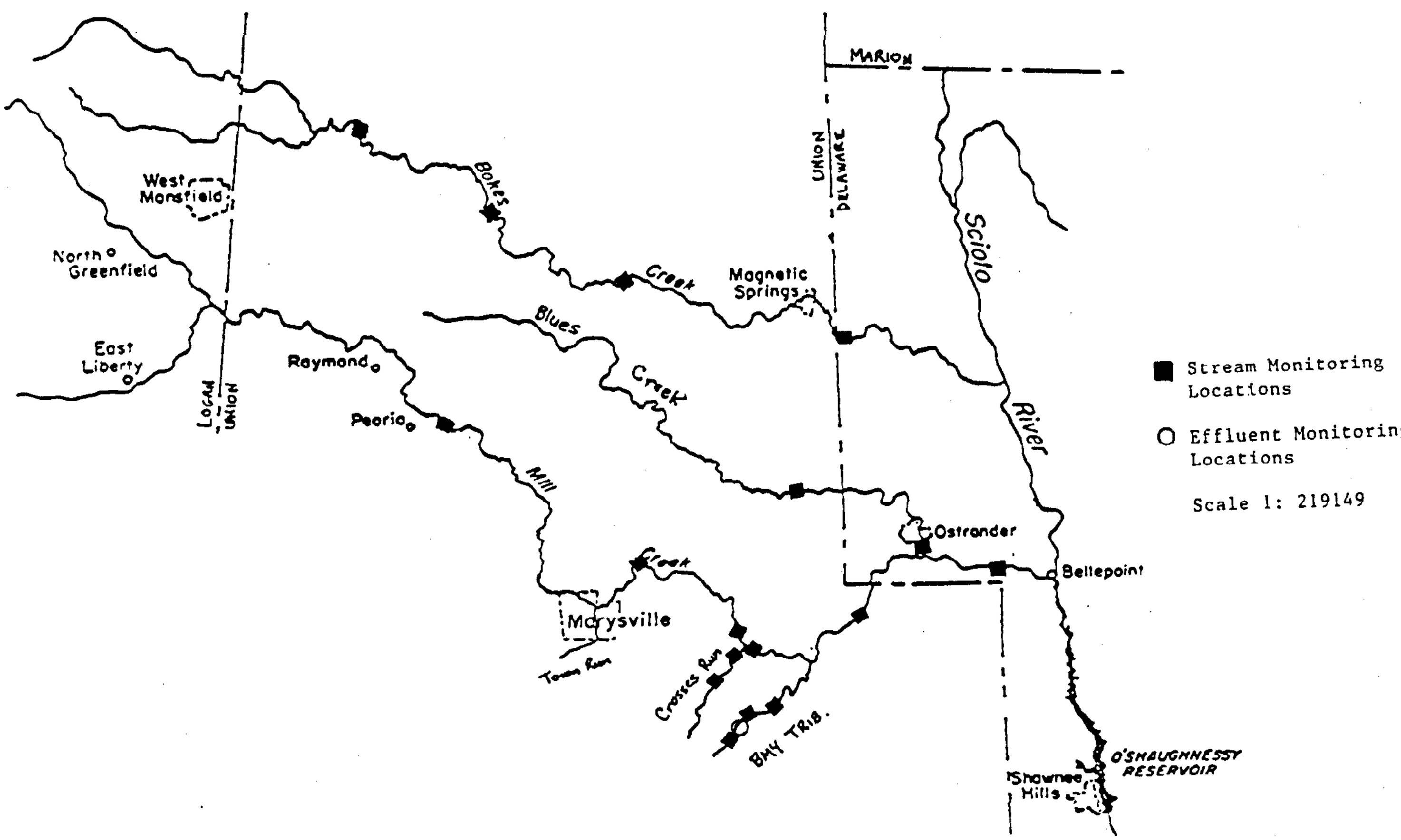


Figure 1. The Mill Creek study area showing principle streams, tributaries, population centers, and pollution sources.

Table 3. Sampling locations (effluent sample - E, water chemistry - C, sediment chemistry - S-C, organics - O, sediment organics S - O, macroinvertebrate - M, fish - F, fish tissue - FT, cross section - Q) in the Mill Creek Study Area, 1990.

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 min. Quad. Map
Mill Creek				
28.2	M,C	40°14'44"/83°26'11"	Ust. Wheeler Gun Rd.	Peoria
28.1	C	40°18'43"/83°26'08"	Wheeler-Green Rd.	Peoria
24.8	F	40°17'25"/83°24'08"	Ust. Cotton Slash Rd.	Peoria
24.7	F	40°17'21"/83°24'03"	Dst. Cotton Slash Rd.	Peoria
19.1	F,C	40°14'23"/83°21'59"	Ust. Town Run	Marysville
19.0	M,F,C	40°14'25"/83°22'02"	Ust. Town Run	Marysville
18.9	C	40°14'19"/83°21'51"	Dst. Town Run	Marysville
18.8	F	40°14'22"/83°21'40"	Dst. Town Run	Marysville
18.6	M,F,C,S-C,O,Q	40°14'23"/83°21'35"	Ust. Marysville WWTP	Marysville
18.3	E,O,Q	40°14'32"/83°21'24"	Marysville WWTP discharge	Marysville
18.2	M,F,C	40°14'33"/83°21'23"	Marysville WWTP Mixing Zone	Marysville
18.1	M,F,C,S-C,S-O	40°14'40"/83°21'16"	Dst. Cherry St.	Marysville
18.0	F	40°14'42"/83°22'30"	Dst. Cherry St.	Marysville
17.0	F	40°15"13"/83°20'45"	Dst. Marysville WWTP	Magnetic Springs
16.9	M	40°15'18"/83°20'44"	Dst. Marysville WWTP	Magnetic Springs
16.8	C	40°15'21"/83°20'43"	Dst. Marysville WWTP	Magnetic Springs
12.2	F,C,S-O,S-C,O F-Tissue	40°13'39"/83°17'53"	Marysville-Hinton Mill Rd.	Marysville
12.1	M	40°13'37"/83°17'56"	Dst. Marysville-Hinton Mill Rd.	Marysville
11.7	M,F,C, F-Tissue S-C,S-O	40°13'21"/83°17'44"	Dst. Crosses Run	Marysville
6.9	M,F,C,F-Tissue O,S-C,S-O	40°13'53"/83°14'22"	Ust. Hinton Mill Rd.	Shawnee Hills
1.8	F	40°14'56"/83°10'31"	Ust. Mills Rd.	Shawnee Hills
1.6	M	40°14'53"/83°10'25"	USGS Gage - Mills Rd. Shawnee Hills	
Crosses Run				
2.1	F	40°12'19"/83°18'46"	Ust. Industrial Parkway	Marysville
2.0	M	40°12'54"/83°18'46"	Ust. Industrial Parkway	Marysville
0.8	F,C,S-C,S-O, O,F-Tissue	40°12'54"/83°18'08"	Ust. Watkins Rd.	Marysville

(Continued)

Table 3. (Continued)

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 min. Quad. Map
Crosses Run				
0.1	M	40°13'05"/83°17'51"	Mouth	Marysville
Town Run				
0.1	M,C	40°14'20"/83°21'56"	Mouth	Marysville
BMY Tributary				
3.4	F	40°11'46"/83°18'33"	Ust. BMY Lagoon	Marysville
3.3	M,F,C,S-C,S-O	40°11'56"/83°18'08"	Old US Rt. 33	Marysville
2.4	M,C	40°12'10"/83°17'17"	US Rt.33 Rest Area	Marysville
Blues Creek				
6.7	F,C	40°16'53"/83°16'17"	Springdale Rd.	Magnetic Springs
6.2	M	40°16'56"/83°15'53"	Dst. Springdale Rd.	Magnetic Springs
0.7	F,C	40°15'42"/83°12'27"	Ust. Ostrander Rd.	Ostrander
0.6	M	40°15'39"/83°12'28"	Ostrander Rd.	Ostrander
Bokes Creek				
27.5	M	40°25'35"/83°28'21"	Ust. Phelps Rd.	York Center
27.2	F	40°25'23"/83°28'24"	York Center - Phelps Rd.	York Center
21.4	M	40°23'33"/83°24'50"	Ust. Yearsley Rd.	York Center
21.3	F	40°23'27"/83°24'45"	Ust. Yearsley Rd.	York Center
14.8	M	40°21'40"/83°21'19"	Claiborne Rd.	Magnetic Springs
13.2	F	40°21'36"/83°19'48"	Ust. Sandusky Rd.	Magnetic Springs
5.6	M,F	40°20'21"/83°14'38"	Dst. Magnetic Springs - Brown Rd.	Ostrander

Methods

All chemical, physical, and biological field, laboratory, data processing, and data analysis methods and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 1987b) and Biological Criteria for the Protection of Aquatic Life, Volumes ll-lll (Ohio EPA 1987c, 1987d), 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 weight information; it is a modification of the original Index of Well-Being applied to fish community information from the Wabash River and other Midwest rivers (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 of the indices does not attain and performance does not fall below the fair category, and NON if all indices either fail to attain or any index indicates poor or very poor performance.

Physical habitat is 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 which generally ranges 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 indicated that values higher than 60 are generally conducive to the establishment of warmwater faunas while those scores in excess of 75-80 often typify habitat conditions which have the ability to support exceptional faunas.

During this survey, macroinvertebrates were sampled using modified Hester/Dendy multiple-plate artificial substrate samplers supplemented with a qualitative assessment of the available natural substrates.

Fish were sampled 1-2 times using either the longline or the towboat pulsed DC electrofishing methods. All chemical/physical and biological sampling locations are listed in Table 3.

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 2). 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.

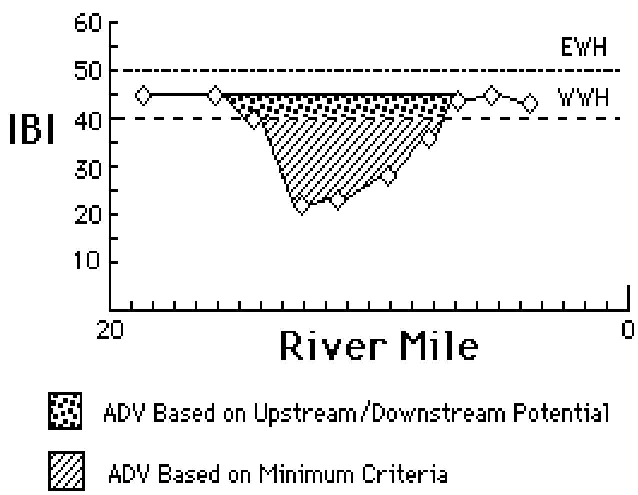


Figure 2. Graphic illustration of the calculation of Area of Degradation Values (ADV) based on upstream potential and the ecoregion warmwater habitat use or minimum criteria (WWH). Criteria for exceptional warmwater habitat use (EWH) is provided for reference.

Results and Discussion

Chemical/Physical Assessment

Ambient Water and Effluent Chemistry

√ Stream flow was an important factor in the collection of the 1990 chemical samples and in the interpretation of the results. Ideally water chemistry sampling should be conducted under summer low flow conditions (*i.e.* at flows that are normally exceeded 70 -80 percent of the time). The flow hydrograph for the U.S. Geological Survey Flow Gage at Bellepoint (Figure 6) and Table 4 indicate that high flows in excess of the 80% flow duration value were the norm during the 1990 field sampling season. Such flows can affect instream chemical concentrations and consequently environmental impacts. Record rainfall totals were recorded throughout Central Ohio in 1990 (Table 5).

Table 4. Mainstream flow from provisional records for the U.S. Geological Survey gage site on Mill Creek near Bellepoint (RM 1.8) for each field date.

DATE	FLOW(CFS)	DURATION(%)[a]
7/12	1060	<10
7/13	2310	<10
7/16	366	<10
7/25	137	<10
7/26	75	<10
8/16	21	30-40
8/17	17	40
8/29	16	40-50
8/30	29	20-30
9/19	16	40-50
9/20	18	30-40
Least value	6.3 (9/4/90)	60-70

a Flow exceeded by the given percentage listed during the period May - November based on information contained in Johnson and Metzger (1981).

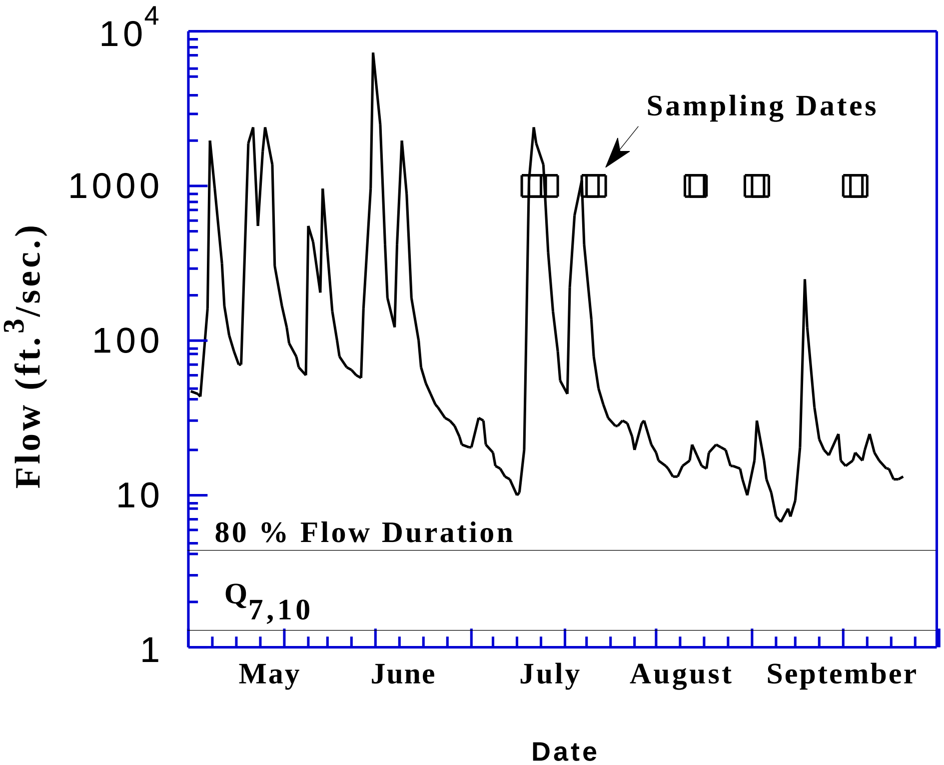


Figure 3. Flow hydrograph for the USGS Water Stage Recorder in Mill Creek near Bellepoint, Ohio (RM 1.8); 1990 with sampling dates, 80% Flow Duration (May-November) and $Q_{7,10}$ (May-November) recorded.

Table 5. Departures from normal precipitation recorded at Marysville by the National Climatic Center for the period May through September, 1990[a].

Month	Rainfall	Departure from normal
May	7.52	+3.80
June	6.72	+2.80
July	7.03	+3.31
August	2.72	-0.55
September	3.97	+1.15

a Personal communication Mike Porter, Ohio Department of Natural Resources, Division of Water.

√ Appendix Table 1 summarizes water chemistry concentrations found at each sampling location in the drainage basin with Table 6 listing water quality criteria exceedences recorded in the Mill Creek/Bokes Creek study area during July - September, 1990.

√ Exceedences of water quality criteria for total iron were found basinwide. Although elevated iron concentrations are technically exceedences of Ohio's Water Quality Standards (WQS), they are also a natural and common phenomenon in Ohio. Ohio's clay soils naturally contain high amounts of iron, so as runoff increases iron concentrations greater than the current 1.0 mg/l WQS frequently occur, when colloidal clay particles remain suspended in the water column.

√ Minor dissolved oxygen exceedences were detected at several sampling sites in the Mill Creek and Bokes Creek basin. Locations include Main St. (RM 19.0) within the city limits of Marysville, downstream from Town Run (RM 18.9), RM 16.8, the approximate location of the 1978 and 1986 D.O. sag, in Crosses Run downstream from O.M. Scott (RM 2.1), in the BMY tributary downstream from BMY Corp. (RMs 3.3 & 2.4) , in Blues Creek (RM 6.7), in Bokes Creek downstream from the W. Mansfield WWTP (RM 27.2) and downstream from Terra International (RM 21.3). All but two of the violations were noted during one sampling run conducted on August 28-30.

√ Ammonia concentrations were slightly elevated (no violations) at the Marysville WWTP discharge suggesting incomplete nitrification of the wastewater. This could be a result of influent water containing metals, thereby adversely affecting the treatment process at the WWTP. No ammonia exceedences were found outside the Marysville WWTP mixing zone in Mill Creek. However this was not the case in Crosses Run. Ammonia exceedences were measured three of the five times sampling was conducted in Crosses Run. Exceedences were found at both sites.

Table 6.Exceedences of Ohio EPA Warmwater Habitat water quality standards criteria (OAC 3745-1) for chemical/physical parameters measured in the Mill Creek study area, July thru September, 1990

Stream Name	Location (River Mile)	Exceedence:Parameter (mg/l unless otherwise noted)
Mill Creek	Wheeler-Green Rd. (28.1)	Fecal Coliform (1020[a],10000[b]), Nitrate (10.9[c])
	Main St.(19.0)	Fecal Coliform (7000[b],3300,11000[b],>60000[b],2000[a])
		Iron,Total(1380[d],1120[d])
		D.O.(4.9[e])
Town Run	3rd St.(0.1)	Fecal Coliform(9000[b],5100[b],59000[b],>60000[b])
		Iron,Total(2820[d],1320[d])
Mill Creek	Dst. Town Run (18.9)	Fecal Coliform(8000[b],4000[b],9000[b],>60000[b],29000[b])
		Iron,Total(1530[d],1380[d])
		Zinc,Total(900[f])
		D.O.(4.3[e])
	Marysville WWTP -	Ammonia-N(5.64[g],2.45[g])
	Effluent(18.26)	Phosphorus,Total(1.37[h],3.62[h],3.62[h],3.96[h],4.89[h])
	Marysville WWTP -	Fecal Coliform(15000[b],2100[a],>60000[b])
	Mix Zone(18.25)	Phosphorus,Total(2.44[h],1.88[h],2.58[h],2.63[h])
		Ammonia-N(3.44[g])
	Cherry St.(18.1)	Fecal Coliform (2100[a],13000[b],5300[b],13000[b],5950[b],17000[b])
		Iron,Total(1720[d],1380[d])
		Phosphorus,Total(1.51[h],1.33[h],1.41[h],1.85[h],1.33[h])
	Brower Property (16.8)	Fecal Coliform(24000[b],>60000[b])
		Iron,Total(1030[d],1910[d])
		D.O.(4.2[e])
		Phosphorus,Total(1.11[h],1.01[h],2.68[h])
	Hinton Mill Rd (12.2)	Fecal Coliform(8000[b])
		Lead, Total(28[g])
		Iron,Total(1730[d],1630[d])
		Phosphorus,Total(1.19[h])
Crosses Run	Industrial Rd. (Old 33)(2.1)	Fecal Coliform(2600[a],4900[a])
		Nitrate(13.7[c],10.2[c])
		Ammonia-N(3.33[g],1.10[g],4.16[g])

(Continued)

Table 6. (Continued)

Stream Name	Location (River Mile)	Exceedence:Parameter (mg/l unless otherwise noted)
Crosses Run	Watkins Rd. (0.8)	Fecal Coliform(5600[b])
		D.O.(4.7[e])
		Ammonia-N(1.07[g],4.81[g],7.75[g])
Mill Creek	Dst. Crosses Run (11.7)	Fecal Coliform(9000[b])
		Iron,Total(1540[d],1580[d])
		Phosphorus,Total(1.02[h])
	Hinton Mill/Bellepoint Rd	Fecal Coliform(17000[b],3700[a])
	(6.9)	Iron,Total(1750[d])
		Lead, Total(24[g])
		Phosphorus,Total(1.13[h],1.09[h])
BMY Tributary	Upstream BMY (3.9)	Fecal Coliform(55000[b],2100[a],5140[b])
		Iron,Total(2330[d])
		Nitrate(14.5[c])
	BMY Lagoon (3.8)	Fecal Coliform(3100[a])
		Iron,Total(4130[d],5970[d])
		Phosphorus,Total(1.02[h])
	BMY Effluent (3.7)	Phosphorus,Total(1.44[h],2.7[h],4.17[h],2.87[h],3.96[h])
		Nitrate(13.0[c],37.6[c],31.4[c],29.4[c])
		Ammonia-N(1.88[g],7.80[g],4.50[g],2.69[g])
		Copper,Total(3540[f],7450[f],3880[f],1590[f])
		Cadmium,Total(4.0[g],14.6[g],8.2[g],14.0[g])
	Industrial Rd. (Old 33)(3.3)	Fecal Coliform(6000[b])
		Copper,Total(55[f],120[f],800[f],230[f])
		Phosphorus,Total(1.51[h])
		Nitrate(13.3[c],19.3[c])
		D.O.(4.7[e])
		Cadmium(3.0[g])
	US 33 (2.4)	Iron,Total(1320[d])
		D.O.(4.4[e])
		Phosphorus,Total(1.04[h])
Blues Creek	Springdale Rd. (6.65)	Fecal Coliform(29000[b])

(Continued)

Table 6. (Continued)

Stream Name	Location (River Mile)	Exceedence:Parameter (mg/l unless otherwise noted)
Blues Creek	Springdale Rd. (6.65)	Iron,Total(1020[d])
		Nitrate(14.2[c])
		D.O.(4.9[e])
	Ostrander Rd. (0.6)	Fecal Coliform(32000[b])
		Nitrate(14.1[c])
Mill Creek	Near Bellepoint (1.8) (USGS Gage Station)	Fecal Coliform(52000[b])
Bokes Creek	Phelps Rd. (27.2)	D.O.(4.4[e],4.9[e])
		Fecal Coliform(14000[b],29000[b],60000[b])
	Yearsley Rd. (21.3)	Fecal Coliform(17000[b],5800[b])
		Nitrate(11.2[c])
		Ammonia(1.35[g])
		D.O.(4.2[e],4.3[e])
	(14.7)	Nitrate(12.7[c])
	(5.6)	Fecal Coliform(3100[a],2000[a])

a Exceedence of the Primary Contact Recreation criteria of 2000 colonies/100 ml.

b Exceedence of the Secondary Contact Recreation criteria of 5000 colonies/100 ml.

c Exceedence of the Outside Mixing Zone Human Health 30-Day Average for Public Water Supply of 10 mg/l of nitrates.

d Exceedence of Outside Mixing Zone 30-day average of 1000 ug/l. for Total Recoverable Iron.

e Exceedence of Outside Mixing Zone Minimum 24-hour average of 5.0 mg/l. for Dissolved Oxygen.

f Exceedence of Outside Mixing zone Maximum.

g Exceedence of Outside Mixing zone 30-day Average.

h Exceedence of the Inside Mixing Zone Maximum Daily Average of 1.0 mg/l.

√ Exceedence of the zinc criterion occurred once in Mill Creek at RM 18.9. A potential source for zinc in this vicinity is runoff from the Eljer Plumbing Facility which is situated on Town Run. Copper exceedences were detected in all BMY Corporation effluent samples (RM 3.4) and in four of five samples collected downstream at RM 3.3. Copper sulfate is used to treat nuisance algal blooms in the BMY lagoon and is a possible cause of these exceedences. Likewise exceedences of the chronic criteria for cadmium were detected in all BMY Corporation effluent samples (RM 3.4) and in one sample collected at RM 3.3.

√ Exceedences of the fecal coliform water quality criteria for both primary and secondary contact recreation were detected basinwide. The cause of these exceedences was probably the result of increased runoff following rainfall events, livestock operations in the two basins, and combined sewer overflow problems.

√ Phosphorus concentrations exceeding the Ohio Water Quality Criterion of 1 mg/l of phosphorus for the prevention of nuisance algal growth were found in the Marysville WWTP mixing zone in four of the five samples taken and immediately downstream at Cherry St. (RM 18.1) in five of the nine samples taken. The number of exceedences declined downstream to Hinton Mill Rd. (RM 6.9) with no exceedences detected downstream. BMY Corp. apparently also has a problem with phosphorus removal. All four of the effluent samples taken exceeded the water quality criterion with exceedences detected as far downstream as US Rt. 33 (RM 2.4). No exceedences were detected in Crosses Run, Blues Creek or Bokes Creek. Normally, elevated water column concentrations of phosphorus drop quickly with downstream distance due to algal uptake. In 1986 toxicity associated with copper from the discharge from Ray Lewis and Sons was thought responsible for the persistence of phosphorus in the water column. Ray Lewis and Sons has since tied into the Marysville WWTP. This action apparently has not eliminated toxicity downstream from the WWTP.

√ Nitrate concentrations exceeding the criteria for a public water supply (10.2-13.7 mg/l) were found in Crosses Run (RM 2.1), in the BMY tributary upstream from the BMY facility (RM 3.9) (14.5 mg/l), in the BMY Corp. effluent (RM 3.7) (13.0-37.6 mg/l) and downstream at RM 3.3 . Elevated nitrate concentrations (14.1-14.2 mg/l) were also detected in Blues Creek at both sites sampled: Springdale Rd. (RM 6.65) and Ostrander Rd. (RM 0.6). In Bokes Creek elevated concentrations (11.2-12.7 mg/l) were found at RM 21.3 and RM 14.7.

Sediment Chemistry

√ Sediment heavy metals concentrations elevated above background were found at *all* sites sampled in the study area (Table 7). Lead and zinc were highly elevated or extremely elevated in concentration in Mill Creek between RM 19.0 and 12.2. Other metals of concern included highly elevated copper concentrations at RM 18.5, highly elevated chromium concentrations at RM 18.1 and highly elevated to extremely elevated concentrations of cadmium and copper in the BMY Corporation receiving stream sediments (RM 3.3). The source of the elevated heavy metals concentrations measured at North Main St. (RM 19.0) is currently unknown. Concentrations of heavy metals, particularly copper lead and zinc, increased dramatically downstream from Town Run. A manufacturer of metal plumbing fixtures, Eljer Plumbing, was situated adjacent to Town Run and presumably may be the source of these metals. Another sampling site with elevated heavy metals problems was downstream from Cherry St. (RM 18.1). The two most likely sources for these elevated concentrations include Ray Lewis and Sons, a metal plating facility that historically batch discharged plating wastes to Mill Creek prior to 1988 and the Eljer Plumbing facility on Town Run. Other possibilities include: the tiered permit for the Marysville WWTP which allows higher loadings of metals, the landfill on which the Marysville WWTP was built (currently being investigated by contractors for the Ohio EPA Division of Emergency and Remedial Response), and the site where Ray Lewis and Sons landfilled their wastes. This entity has recently tied all process wastewaters to the Marysville WWTP.

√ Sediment organic chemical contaminants were found at all sites sampled in the study area (Table 8). PCBs, common contaminants at least at the trace level, were not found in the study area. Endosulfan sulfate and highly elevated levels of DDT and its metabolites were measured in sediment samples at Cherry St. (RM 18.1), downstream from the Marysville WWTP. Contamination by these compounds at elevated levels extended downstream to RM 11.7, which is downstream from Crosses Run. Recent investigations by the USEPA of the landfill that the Marysville WWTP is sited on has revealed the presence a variety of pesticides, PCBs, volatile and semi-volatile organic compounds. The landfill, therefore, is a logical source for DDT and other organic contaminants instream. Effluent from the Marysville WWTP may also be a potential source of contamination. Heptachlor, dieldrin and DDT were measured at the highly to extremely elevated level in Crosses Run (RM 0.8). Endosulfan sulfate was also present at the two sampling sites in this tributary. Endosulfan sulfate is a breakdown product of endosulfan, a pesticide that is used on a wide variety of crops. Samples taken in Crosses Run, upstream from Industrial Parkway, had much lower concentrations of DDT and no detectable concentrations of heptachlor or dieldrin. The source of these chemicals in Crosses Run, therefore, appears to be the unnamed tributary that flows pass the O.M. Scott treatment lagoons and/or runoff from test plots in the vicinity. This tributary was also the source of a large spill that occurred on May 3, 1987. A rupture in a pipeline spilled 35000 gallons of recycle water into Crosses Run containing ammonia (1200 ppm.) which resulted in a major fish kill in Crosses Run and Mill Creek. Also detected in the soils of the spill site were elevated levels of atrazine, diazinon, 2,4 - D, diphenamid and arsenic. The O. M. Scott facility historically has been a chronic and sporadic source of both nutrient and pesticide pollution of Crosses Run/ Mill Creek due to malfunctions during wastewater transfer operations, in conjunction with a general lack of associated pollution control engineering features (Ohio EPA DERR files).

√ Pesticide data was not collected in Mill Creek upstream from RM 18.1 due to a limited laboratory sample allocation. No other priority pollutants were detected in any organics samples collected as part of the survey .

Table 7. Concentration of heavy metals in sediments of the Mill Creek Study Area, 1990.[1]

LOCATION	**River Mile**	**Sediment Concentration (mg/kg. dry weight)**						
		As	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Zn**
Mill Creek								
North Main St.	19.0	13.2[c]	1.01[c]	33.7[c]	45.5[b]	**80.7[d]**	33.7	**209[d]**
Dst.Town Run	18.5	10.1[b]	1.01[c]	37.2[c]	**147[d]**	**197[e]**	29.8	**333[e]**
At Cherry St.	18.1	5.41[a]	0.947[b]	**48.2[d]**	96.1[c]	**108[e]**	57.4	**254[d]**
At Hinton Mill Rd	12.2	9.78[b]	0.535[b]	35.1[c]	40.7[b]	**63.3[d]**	35.7	122[c]
Dst. Crosses Run	11.7	9.33[b]	0.706[b]	32.9[c]	36.8[a]	38.4[c]	37.2	126[c]
At Hinton Mill/ Bellepoint Rd.	6.9	10.2[b]	0.485[a]	30.9[c]	31.0[a]	58.7[c]	31.7	103[c]
Crosses Run								
At Indust Pkwy.	2.1	5.96[a]	0.572[b]	23.2[c]	33.6[a]	37.8[b]	21.8	153[c]
At Watkins Rd.	0.8	9.62[b]	0.447[a]	28.9[c]	27.0[a]	38.5[c]	26.9	126[c]
BMY Tributary								
At Indust. Pkwy.	3.3	7.65[a]	**2.52[d]**	14.4[a]	**576[e]**	16.1[a]	26.0	74.2[a]

1 All parameter concentrations, excluding nickel, were ranked on a stream sediment classification system described by Kelly and Hite (1984).

a Non-elevated

b Slightly elevated

c Elevated

d Highly elevated

e Extremely elevated

Note: The Kelly and Hite classification system addresses relative concentrations but does not directly assess toxicity.

Table 8. Concentration (ug/kg) of Pesticides/PCBs in the sediments of the Mill Creek study area, 1990.[1,2]

Location	River Mile	Hepta-chlor	Aldrin	Dieldrin	Endo-sulfan II	Endosulfan sulfate	DDT Total
Mill Cr							
At Cherry St	18.1	---	---	---	---	49.28[f]	**154.83[d]**
At Hinton Mill Rd	12.2	---	---	---	---	19.54[f]	---
Dst.Crosses Run	11.7	---	---	8.80[c]	---	16.69[f]	7.83[b]
at Hinton Mill/ Bellepoint Rd.	6.9	---	---	---	---	---	3.27[a]
Crosses Run							
At Indust Pkwy	2.1	---	---	---	---	27.45[f]	14.41[c]
At Watkins Rd	0.8	**8.81[d]**	---	**19.11[d]**	---	32.36[f]	**492.01[e]**
BMY Trib							
At Indust Pkwy	3.3	---	1.29[f]	5.39[b]	1.99[f]	---	---

1 All pesticide concentrations were ranked on a stream sediment classification system described by Kelly and Hite (1984).

2 No PCBs detected in sediment samples.

a Non-elevated

b Slightly elevated

c Elevated

d Highly elevated

e Extremely elevated

f Not evaluated by Kelly and Hite (1984)

Note: The Kelly and Hite classification system addresses relative concentrations but does not directly assess toxicity.

Bokes Creek

Bokes Creek, located in northern Union County, Ohio, drains 745 square miles. Four potential pollution point sources are situated within the basin including: the West Mansfield WWTP, the Daylay and Mad River Egg Farms, and a bulk fertilizer facility operated by Terra International located on SR 31 in Sommersville. Several potential nonpoint sources of pollution are present within the basin. Chemical/physical sampling sites were chosen to determine the impact of these potential pollution sources. Chemical/physical samples were collected five times during July-September, 1990 . It should be noted that flow during this period was unusually high due to precipitation (Table 9).

Table 9. Flow measured at the USGS Monitoring Gage in Bokes Creek near Ostrander, Ohio for the dates sampled during 1990.

Date	**Flow** (CFS)
7/11/90	6.70
7/24/90	362.00
8/15/90	35.00
8/28/90	5.80
9/18/90	16.00

Water chemistry data revealed problems with nutrient enrichment in Bokes Creek probably from both point and non-point sources of pollution. The upstream site, Phelps Rd. (RM 27.2), is approximately three miles downstream from the confluence with a small tributary that receives the effluent from the West Mansfield WWTP. Three exceedences of the secondary contact recreation WQS for fecal coliform (2000 colonies/100ml.) were observed during the period of study at this site. Additionally, two small exceedences of the minimum WQS criteria for D.O. were also detected (Table 10). No other WQS exceedences were detected at this site, however, nitrate levels as high as 9.20 mg/l were found on July 24 during a period of very elevated flows (362 CFS) suggesting nonpoint source runoff impacts.

The next site downstream, Yearsley Rd. (RM 21.3), was approximately 0.5 miles downstream from the Terra International bulk fertilizer facility. On two occasions the fecal coliform WQS criterion was exceeded at this site (Table 10). Nitrate levels were also elevated (*i.e.* 11.2 mg/l - July 24, 1990). Since nitrate concentrations were also elevated at the three other sites in Bokes Creek on the same date this facility was not solely responsible. However, Terra International has documented problems with leakage of anhydrous ammonia at its other facility, which is situated on an unnamed tributary to Mill Creek. If similar chemical storage and handling practices are followed instream impacts may be expected. Supporting this concern, one exceedence of the Outside Mixing Zone 30 - day average for ammonia was detected at RM 21.3. Dissolved oxygen also dipped below the daily minimum criteria on two occasions.

Measured concentrations of nitrates and phosphorus were not consistently greater at RM 14.85, downstream from the confluence with Powderlick Run, than at the site upstream (RM 21.3) in 1990. The Daylay and Mad River Egg Farms are both sited in this small subbasin and routinely land apply poultry wastes to crop lands in the vicinity. The lack of major differences in concentrations of nutrients upstream and downstream from Powderlick Run may result from the location of land application areas and the high stream flows recorded in 1990 diminishing the relative contribution from Powderlick Run. A study conducted from March 1989 to October 1989 in Powderlick Run and upper Blues Creek revealed that although concentrations of nitrates never exceeded current WQS criteria values in Powderlick Creek, they consistently exceeded the control watershed between 2/28/89 and 6/13/89. Additionally, during the peak spring runoff period when nitrates are of particular concern for Ohio's public water supplies, nitrates in the Powderlick subbasin exceeded the 10 mg/l alert level on all dates sampled and on one occasion by as much as fives times the alert level (Ohio EPA 1990).

The only exceedences of WQS criteria at the downstream site, RM 5.55, were two exceedences of the primary contact recreation standard for fecal coliform.

One method to determine the relative contributions to a nutrient enrichment/ dissolved oxygen problem associated with agricultural run-off or domestic sewage is by calculating the fecal coliform/fecal streptococcus ratio (FC/FS). This method of distinguishing between animal waste and human waste is not without bias and should be approached cautiously (Wheater and Mara 1979). It was suggested by Gelreich (1976) that a FC/FS ratio of greater than 4.0 indicates primarily human fecal pollution, while a ratio lower than 0.7 indicates animal waste. Fecal coliform and fecal streptococcus concentrations were elevated on several occasions at all sites sampled at a variety of flows (Table 11). The ratios were lower than 0.15 when the flow at the gaging station was 1420 cfs and also when the flow was measured at 6.7 cfs. Two sources of animal waste in the Bokes Creek basin are livestock and poultry operations and land application of animal wastes. Land application may cause elevated fecal bacteria during periods of high flow with discharge from a WWTP treating livestock wastes the suspected source during lower flow periods. Moderate flows yielded ratios suggesting human waste was responsible for the elevated fecal bacterial counts, perhaps from West Mansfield WWTP and failing on-site systems.

In summary, the water chemistry sampling results revealed moderate organic enrichment problems in Bokes Creek in 1990. Potential for impacts exist from both point and nonpoint sources of pollution. The load allocation study planned for the 1992 field season should permit a better delimitation of the stress and impacts associated with various sources of point and nonpoint sources of pollution in Bokes Creek.

Table 10. Exceedences of Ohio EPA Warmwater Habitat water quality criteria (OAC 3745-1) for chemical/physical parameters measured in the Bokes Creek study area July - October, 1991.

Site (River Mile)	Violation : Parameter
27.20	Fecal coliform[a] (29000, >60000)
21.30	Fecal coliform[a] (28000, >60000)
5.55	Fecal coliform[a] (3100, 2000)

Table 11. Densities of fecal coliform and fecal streptococcus colonies counted from water samples collected Bokes Creek during July - September, 1990.

Date	Site (RM)	Fecal Coliform (#/100ml)	Fecal Streptococcus(#/100ml)		Flow Ratio (CFS)
7-11-90	27.20	14000	>16000	0.03	6.7
7-14-90		500	11000	0.05	1420.0
8-15-90		29000	680	42.60	35.0
8-28-90		>60000	453	132.50	5.8
7-11-90	21.30	17000	4500	3.78	6.7
7-14-90		880	9000	0.01	1420.0
8-15-90		28000	220	263.60	35.0
8-28-90		310	100	3.10	5.8
9-18-90		493	90	5.48	13.0
7-11-90	14.85	760	>60000	0.01	6.7
7-14-90		1080	7000	0.15	1420.0
8-15-90		920	260	3.54	35.0
8-28-90		270	300	0.90	5.8
9-18-90		680	160	4.25	13.0
7-11-90	5.55	3100	>60000	0.05	6.7
7-14-90		1600	21000	0.03	1420.0
8-15-90		880	270	3.26	35.0
8-28-90		330	140	2.36	5.8
9-18-90		2000	170	11.77	13.0

a #/100ml

Trends - Water Chemistry

Influent and Effluent Chemistry

√ Although influent concentrations of some heavy metals to the Marysville WWTP have declined since 1981, including copper and cadmium, (Figure 4) other metals including chromium, lead, and nickel have markedly increased between 1988 and 1990 (Figure 5). Average influent concentrations of zinc increased gradually throughout the same period. Third quarter effluent loadings from the Marysville WWTP also revealed increases in heavy metals (Figure 6). Chromium, nickel, lead and zinc loadings increased between 1986 and 1990 (Figure 7). Ray Lewis and Sons, a metal plating operation and potential source of heavy metals, connected all process wastewaters to the Marysville WWTP in 1988. This may explain the marked increase heavy metals treated by the WWTP particularly chromium, lead and nickel. Another source may be the two Honda plants. The Honda Marysville Plant first tied into the Marysville WWTP in 1982 with the East Liberty Plant connecting in April of 1990. There may be some correlation in the increase in metals loadings to the WWTP with production figures from these two facilities. Additionally, the flow tiered permit for the Marysville WWTP which allows higher loadings fro metals may also contribute to elevated sediment concentrations.

√ Third quarter Liquid Effluent Analysis and Process System (LEAPS) loading data for the Marysville WWTP revealed increases in total plant flow, BOD and ammonia loadings (Figure 6) between 1986 and 1990. Nitrate loadings, however, declined during the same period. This trend, in conjunction with the observed increases in ammonia loadings, may reflect a reduction in nitrification efficiency at the recently upgraded Marysville WTTP resulting from the increased loadings of heavy metals to the WWTP.

√ Third quarter LEAPS loadings data between 1986 and 1990 for BMY Corporation (Figure 8) show substantial increases in flow and ammonia loadings particularly in 1989 and 1990. This entity discharges to a headwater stream. No discernible increase was noted in Mill Creek downstream from the confluence with the BMY tributary. A new treatment plant is scheduled to go online in October or November, 1991. Monitoring should be conducted to determine the impact of the new facility on loadings.

Ambient Chemistry

√ Instream concentrations of lead and zinc steadily declined at Cherry St. (RM 18.1) from the late 1970s to 1990 signalling the elimination of direct discharges, improvements in the pretreatment of industrial wastes and improvements in wastewater treatment (Figure 9).

√ Mean and minimum dissolved oxygen concentrations measured at Cherry St., although exhibiting considerable variability, have generally increased since the late 1970s (Figure 10). Modest declines were noted in 1990. Biological oxygen demand concentrations peaked in the early 1980s, declined sharply in 1984 and then steadily increased till 1989. The significant drop measured in 1990 documents the increased efficiency of removal of oxygen demanding substances at the upgraded Marysville WWTP.

√ Ammonia concentrations have declined steadily at Cherry St. since the early 1980s (Figure 11). Nitrates on the other hand have increased gradually through the same period, although reductions have been documented since 1988 coinciding with the upgrade at the Marysville WWTP (Figure 11).

√ Sampling conducted during the 1986 survey of Mill Creek revealed total phosphorus and nitrate values elevated downstream from the Marysville WWTP which remained high throughout the remainder of the mainstem. The highs for phosphorus were as great as three times the 1990 values immediately downstream from the WWTP (RM 18.1). Downstream from the WWTP toxicity preventing the utilization of the phosphorus by algal growth was the suspected cause for the elevated levels measured in 1986. A sharp increase in algal productivity during a two week shutdown of the Ray Lewis metal plating facility during 1978 lead to this conclusion.

The City of Columbus, Division of Water routinely monitors selected water chemistry parameters at the USGS Gaging Station in Mill Creek at Bellpoint, Ohio. A plot of their monthly sampling results of phosphorus versus stream flow between February, 1988 and September, 1989 revealed that during certain periods elevated concentrations of phosphorus were associated with low flow, a characteristic of point, not, nonpoint sources of pollution (Figure 12). Peaks in nitrate concentrations in 1990, however, coincided with peaks in flow indicating elevated nitrate concentrations were driven by nonpoint sources of pollution (Figure 13). Increased efficiency in the removal of phosphorus at the upgraded Marysville WWTP probably accounts for some of the reduction in phosphorus peaks as does the elimination of Ray Lewis and Sons' direct discharge to Mill Creek. This would presumably reduce the toxicity documented downstream from the WWTP and result in more instream uptake of phosphorus. Measured increases in phosphorus downstream from the BMY tributary point to the BMY Corp. as another potential contributor to elevated phosphorus concentrations in Mill Creek. Several samples analyzed from this tributary exceeded the 1.0 mg/l. threshold. All nitrogen compounds measured showed a trend of decline downstream from the Marysville WWTP to the confluence with Crosses Run, then some compounds recorded marked increases, as large as six to nine fold. Elevated concentrations of nitrogen bearing compounds at one site, but not the other when sampled on the same day indicate a pulsed discharge to Crosses Run present upstream from Industrial Parkway (Appendix Table C-1). Dischargers to this tributary may be responsible the high values seen at the mouth since highs values were measured in Crosses Run during low flow periods.

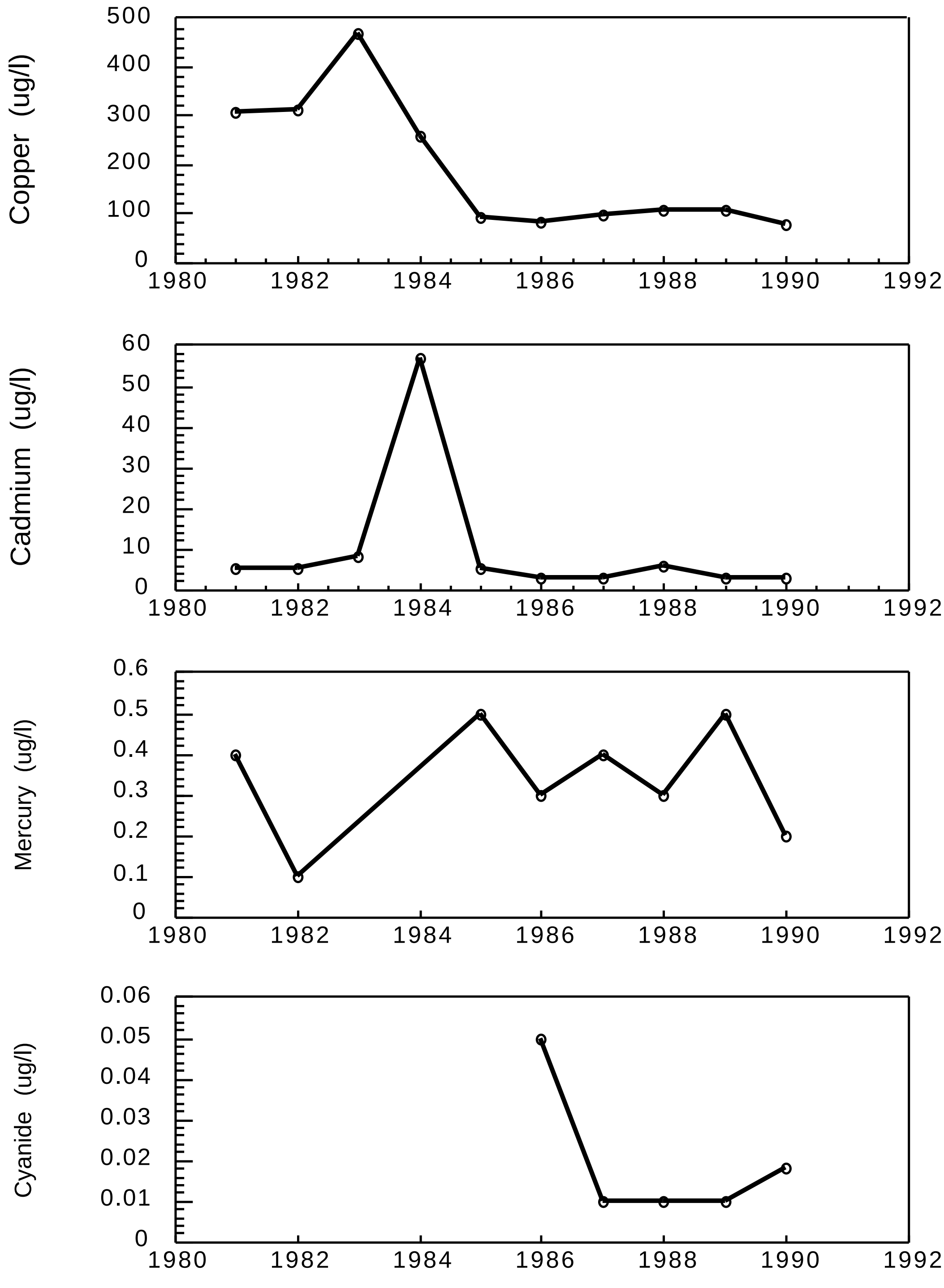


Figure 4. Historical trends in the concentration of copper, cadmium, mercury and cyanide in the influent to the Marysville WWTP from 1980 to 1992.

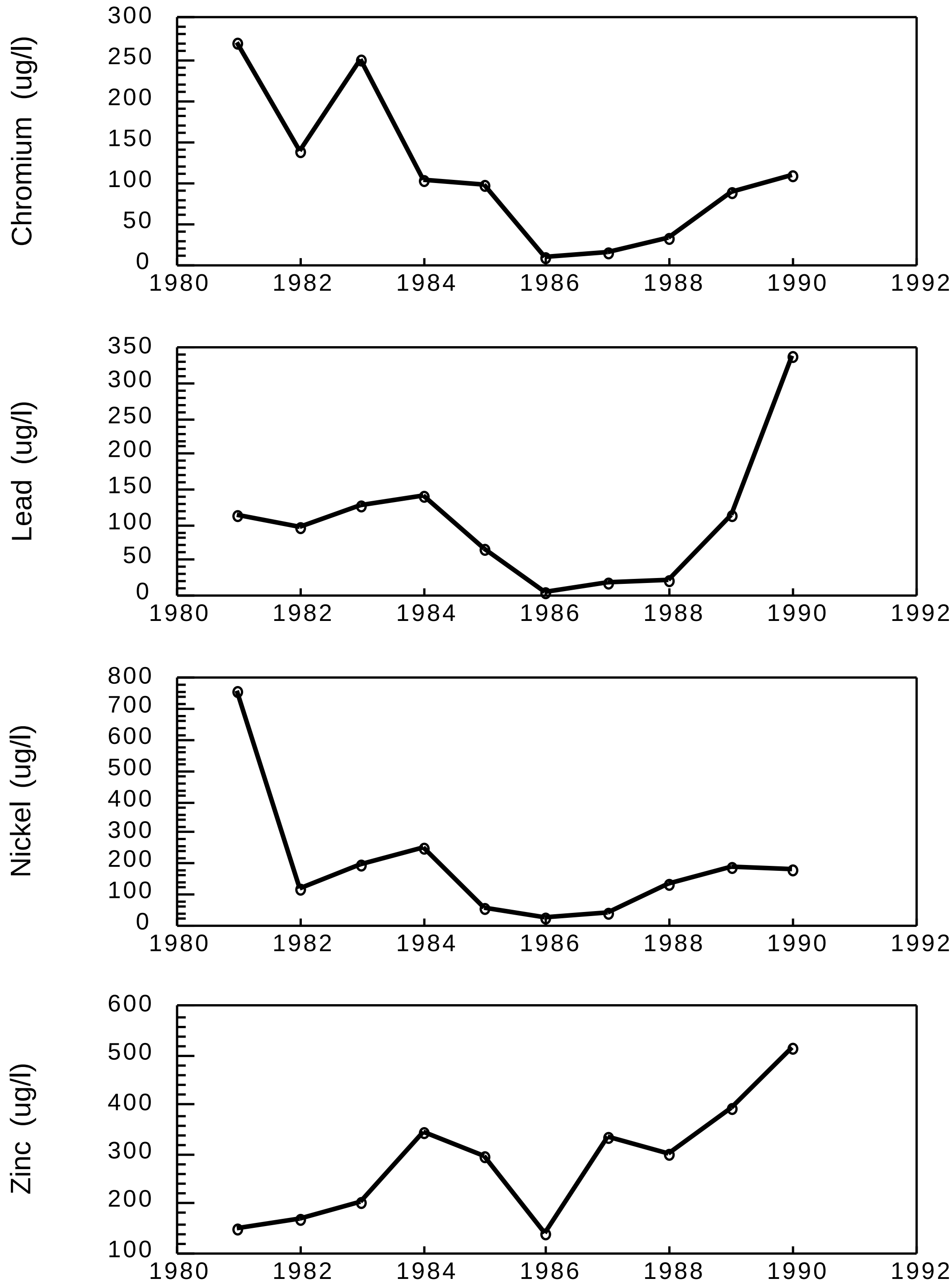


Figure 5. Historical trends in the concentration of chromium, lead, nickel and zinc in the influent to the Marysville WWTP from 1980 to 1992.

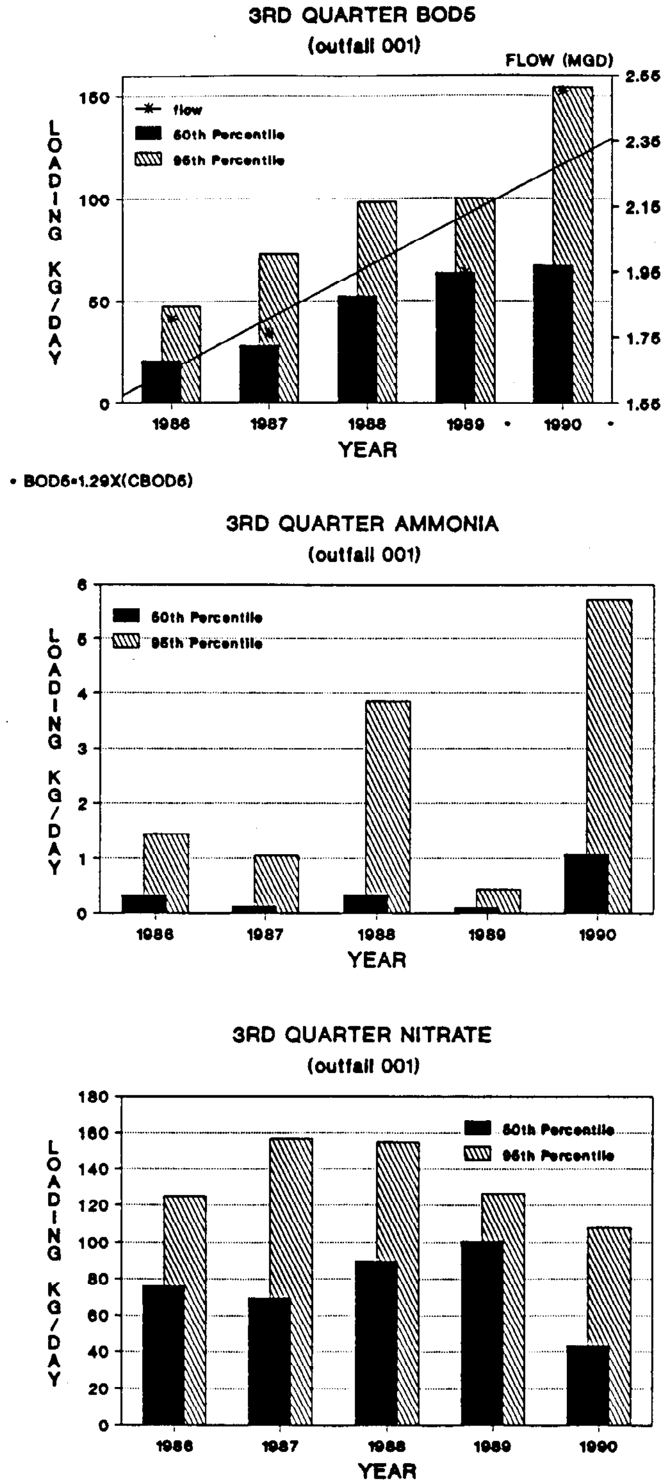


Figure 6. Historical trends in the third quarter loadings from the Marysville WWTP for Biochemical Oxygen Demand (BOD_5), ammonia, and nitrate between 1986 and 1990.

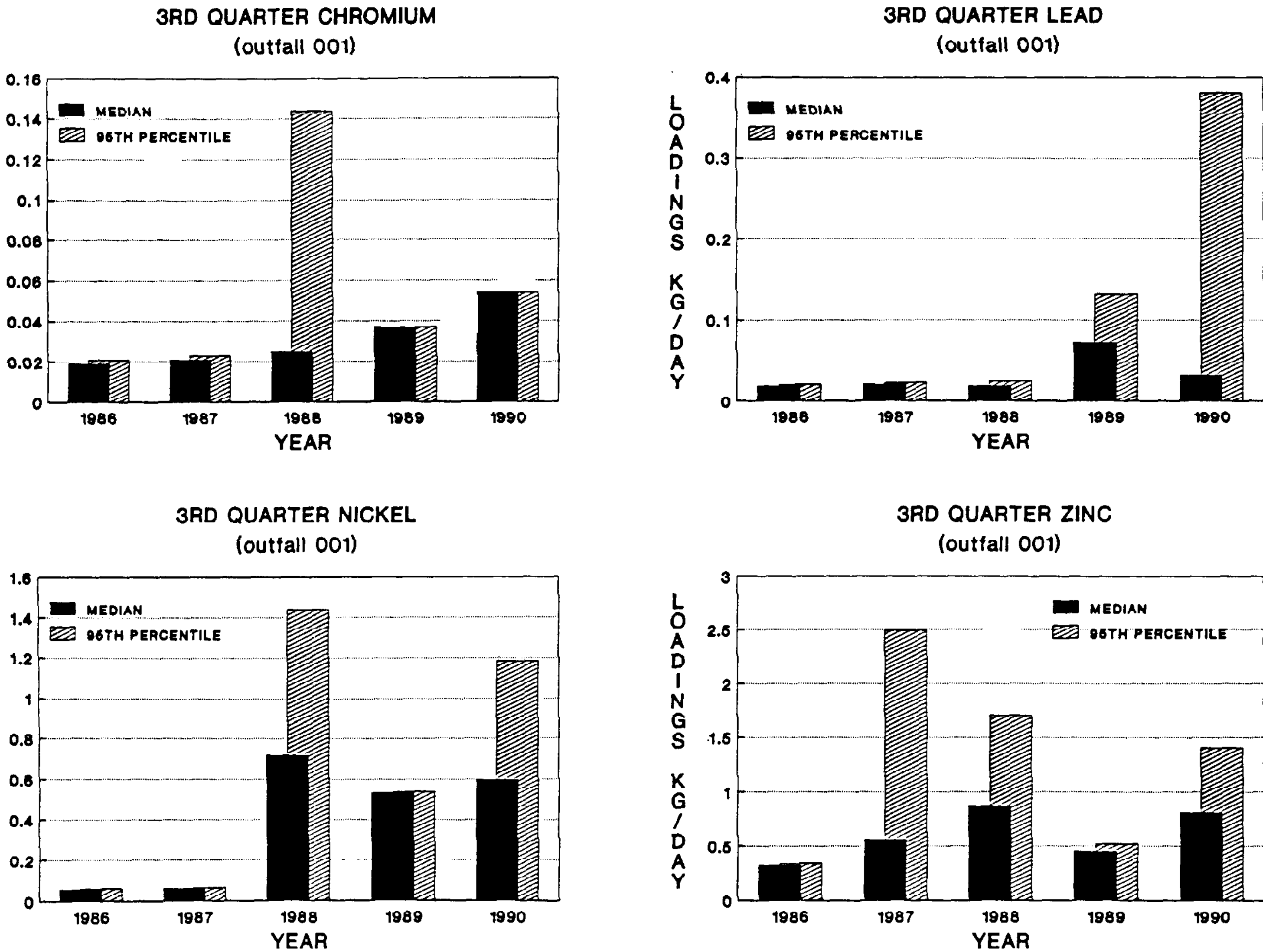
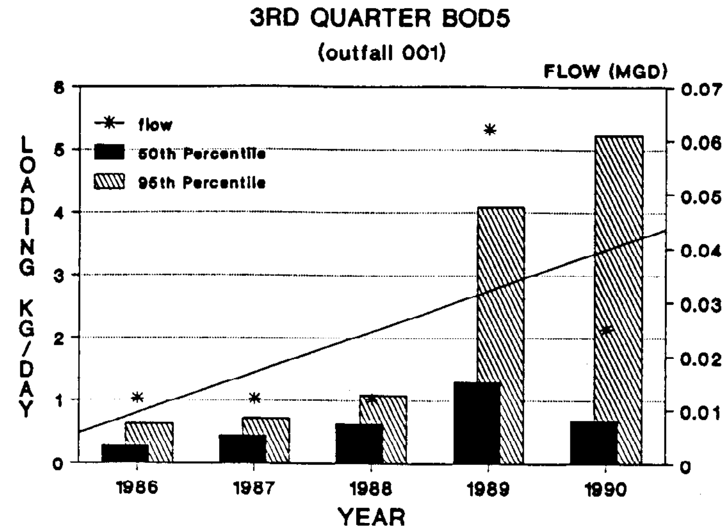


Figure 7. Historical trends in the third quarter loadings from the Marysville WWTP for chromium, lead, nickel and zinc between 1986 and 1990.



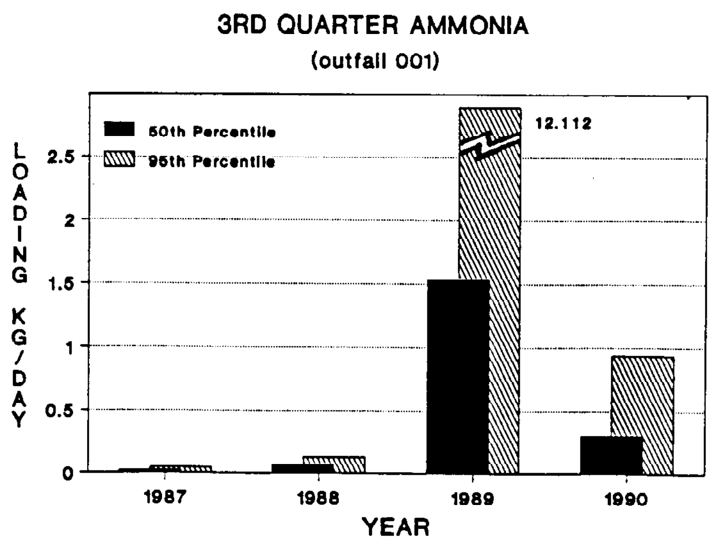
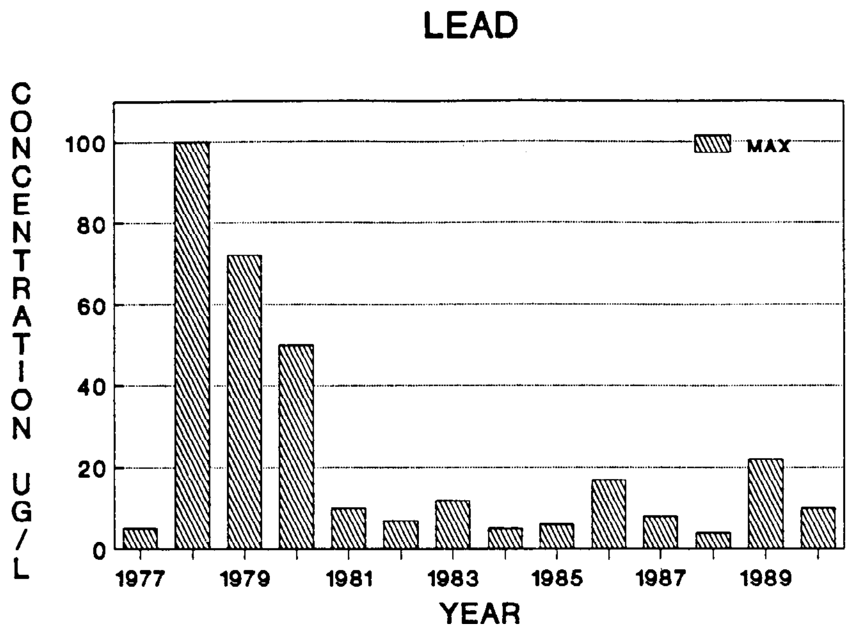


Figure 8. Historical trends in the third quarter loadings from the BMY Motorized Vehicle Facility for Biochemical Oxygen Demand (BOD_5) and ammonia between 1986 and 1990.



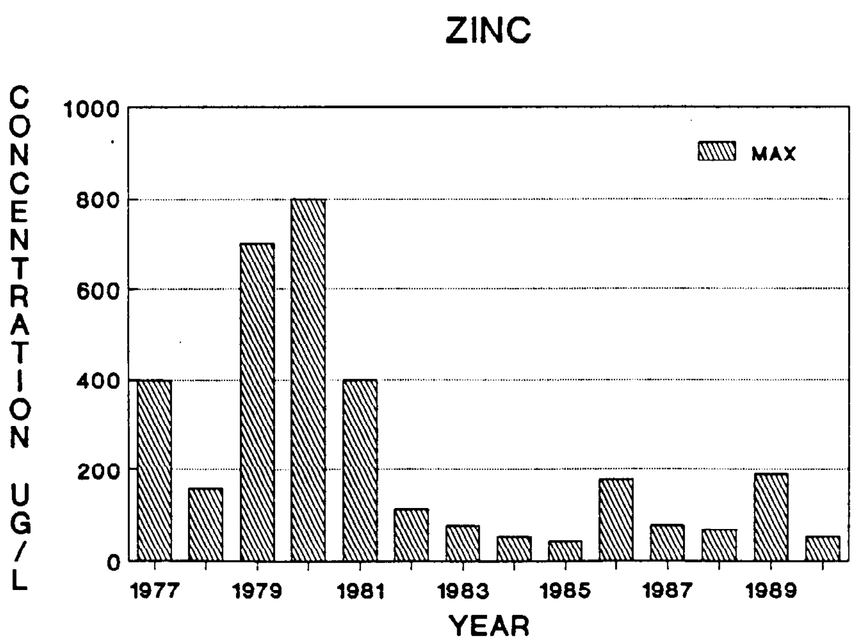
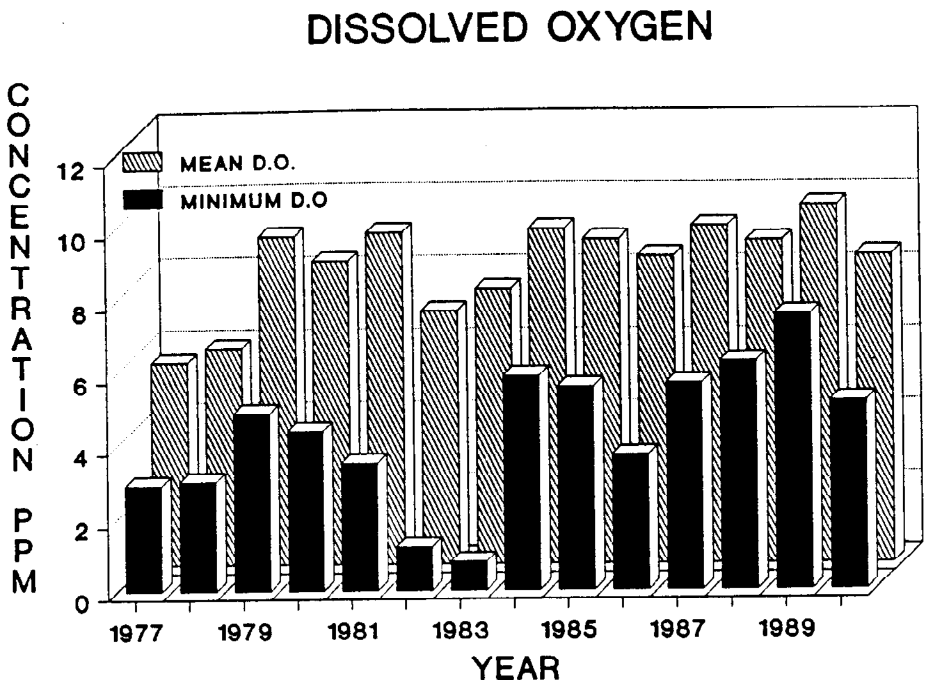


Figure 9. Historical trends in the instream concentrations of lead and zinc measured at Cherry St. (RM 18.1) between 1977 and 1990.



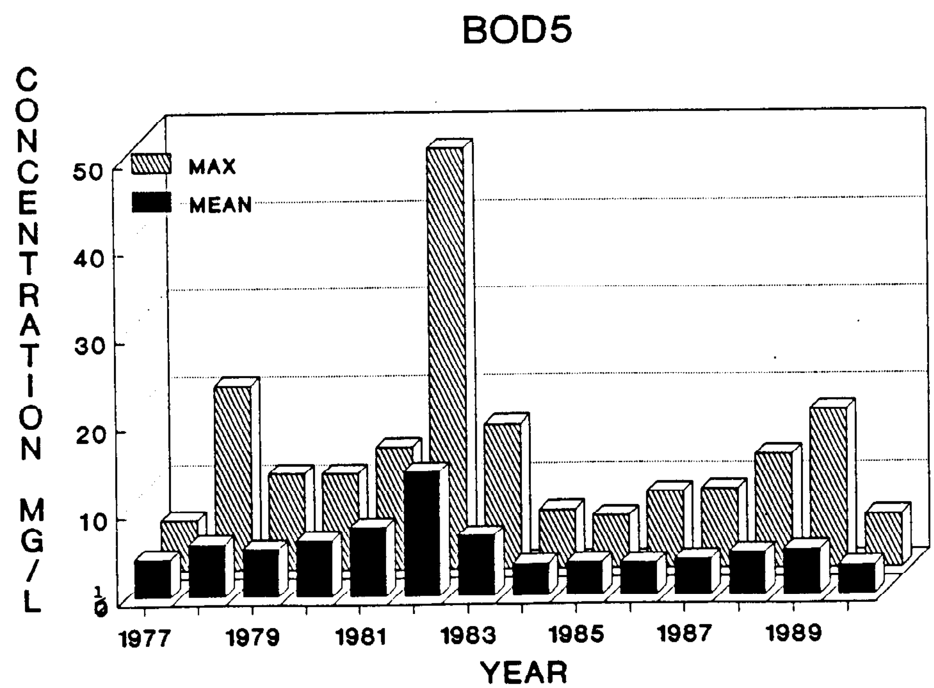


Figure 10. Historical trends in the instream concentrations of dissolved oxygen and Biochemical Oxygen Demand (BOD_5) measured at Cherry St. (RM 18.1) between 1977 and 1990.

Habitat Assessment

Mill Creek

To determine the biological potential and use attainability of a given stream segment requires the analysis of the riparian and instream habitat characteristics, disturbance type, potential rate of recovery, and plans for maintenance of modifications (Rankin 1989). Table 12 presents a matrix of Warmwater Habitat characteristics, Modified Warmwater Habitat characteristics (further broken down to characteristics that have high influence or moderate influence on altering community performance) and individual site habitat characteristics for use in helping to determine the appropriate aquatic life use of a stream segment.

Instream and riparian habitats were largely similar to those documented in 1986. Noteworthy exceptions were found at RM 24.8, downstream from Cotton Slash Rd., where a short reach of the stream bed was actively being channelized, and at RM 18.27 where the stream was impounded by a flow monitoring dam/weir constructed for the recently upgraded Marysville WTTP.

The Qualitative Habitat Evaluation Index (QHEI) in Mill Creek ranged from 58.5 at RM 24.8 to 76.5 at RM 12.2 (Table 12). The mean QHEI score for the Mill Creek mainstem was 66.3. Comparison of QHEI scores with biological performance of sites in the Ohio EPA database has shown that segments with average scores higher than 60 are easily capable of achieving the Warmwater Habitat (WWH) aquatic life use designation criteria based on habitat alone. It is important to note that this evaluation stresses the analysis of habitat characteristics of a segment and not of individual sites. 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 if other water resource parameters are adequate the reverse can also be true. Therefore with a mainstem average QHEI of 66.3, Mill Creek is physically capable of supporting its existing designated WWH aquatic life use.

Crosses Run

The downstream portions of Crosses Run provide instream and riparian habitat adequate for supporting headwater Warmwater Habitat aquatic communities (QHEI = 60). Upstream portions of the stream have been physically altered with portions riprapped and the riparian canopy removed. The stream in this area, however, retains its natural sinuosity. If native vegetation was permitted to re-establish natural recovery processes would yield habitat similar to that found in the downstream reaches.

Bokes Creek

The Ohio EPA Nonpoint Source Assessment (Ohio EPA 1990) lists Bokes Creek as being impaired from its headwaters to the confluence with Brush Run by the following types of nonpoint source pollution: general agricultural run-off, crop production, livestock production, pasturage, channelization and on-site wastewater treatment systems. Downstream from Brush Run to the mouth it is listed as impacted by the same types of NPS pollution as upstream. Warmwater habitat attributes, however predominate at sites evaluated in Bokes Creek (Table 121). The only high influence modified attribute found at a majority of the sites sampled was instream cover that was absent or sparse in abundance. Moderate influence modified habitat attributes found at the two upstream sites included stream channels recovering from channelization, heavy to moderate silt cover, fair to poor stream development and high to moderate substrate embeddedness. The mean QHEI score for Bokes Creek of 67, however, suggests that the instream and riparian physical habitat is more than capable of supporting a WWH aquatic community.

Blues Creek

Blues Creek is listed by the Ohio EPA Nonpoint Source Assessment (Ohio EPA 1990) as impacted from its headwaters to its mouth by general agricultural run-off, crop production, livestock production, pasturage, channelization and on-site wastewater treatment systems.

Instream habitat changes resulting from nonpoint source impacts were apparent in Blues Creek, especially in the upstream portions of the basin. The area in the vicinity of RM 6.7 had obviously been channelized in the past which has reduced stream sinuosity, diversity in riffle, pool, run development, habitat structure and has increased erosion. Additionally, livestock had free access to the stream in this area which resulted in false banks, broader and more uniform stream cross sections, less diversity in instream cover and increased erosion. A heavy layer of silt was evident in the slack water areas throughout this sampling zone. The downstream site showed significant improvement, some of it attributable to reduced access to the stream by livestock and the higher gradient. Higher gradients tend to flush out contributed sediments at a faster rate than lower gradients.

The upstream portions of Blues Creek possessed very few Warmwater Habitat attributes, one high influence Modified Warmwater Habitat attribute, sparse to no instream cover, and a preponderance (7) of moderate influence Modified Warmwater Habitat attributes including: recovery from channelization, heavy to moderate silt cover, fair to poor riffle, pool, run development, low to no sinuosity, lack of fast currents, high to moderate embeddedness and extensive to moderate riffle embeddedness. Additionally, Blues Creek is a petitioned ditch from west of SR 4 (RM 11.85) to its headwaters (W. Galloway, Union County Engineers Office, personal communication). Inspection of 7 1/2 minute topographic maps indicated extensive channel modifications in the entirety of the upper watershed. Due to the recurring disruption of the physical habitat that the ditch maintenance will entail, the existing extensive modification of the instream and riparian habitat, and the absence of potential for recovery of sufficient WWH attributes, the more appropriate aquatic life use designation for this segment would be Modified Warmwater habitat (MWH).

Biological Assessment

Macroinvertebrate Community

Mill Creek Mainstem

Artificial substrate samples were collected at ten mainstem stations from RM 28.2, upstream from Marysville, to RM 1.6, downstream from Blues Creek. Narrative evaluations based on ICI scores ranged from very good (ICI = 42 at RM 28.2) to fair (ICI = 14 at RM 18.2 and 18.1) (Table 13).

Macroinvertebrate communities upstream from Marysville exceeded the WWH ICI criterion and reflected very good water quality conditions (ICI = 42 at RM 28.2) (Figure 15). Historically, samples upstream from Marysville were collected at RM 25.1 but the site was moved upstream in 1990 due to channel modifications at that site.

In Marysville the ICI declined into the fair range upstream from Town Run (22 at RM 19.0) and fell to 18 downstream from the confluence at RM 18.6. Artificial substrate samples may have been influenced by slow current velocities at RM 19.0 and a large accumulation of detritus and solids at RM 18.6. However, the loss of numerous pollution sensitive taxa on the natural substrates and shifts in predominance to more pollution tolerant blackflies (RM 19.0) and midges (RM 18.6) were indicative of declining water quality conditions through Marysville. Community composition at RM 19.0 suggested an impact from organic enrichment while downstream from Town Run, community composition suggested both enrichment and toxic influences. Qualitative sampling from the mouth of Town Run reflected poor water quality conditions and detectable toxicity.

ICI scores dropped to the low fair range in the Marysville WWTP mixing zone and immediately downstream (14 at RM 18.2 and 18.1, respectively). Both samples were similar in composition and notable in the predominance of the toxics tolerant midge Cricotopus bicinctus and the absence of the more toxicity sensitive midges of the Tribe Tanytarsini. Community composition at these sites had some characteristics of both sewage and toxic influences, but the predominant near field impact appeared related to toxicity.

Stations downstream from Marysville gradually improved over the next six river miles reaching a marginally good level upstream from Crosses Run (i.e. ICI = 32 at RM 12.1). Sharp increases in the numbers of hydropsychid caddisflies and tanytarsini midges and corresponding decreases in the abundance of tolerant dipterans and other non-insect taxa documented the improvements at RM 12.1.

Recovery was interrupted at RM 11.7, downstream from the confluence with Crosses Run, where the ICI of 26 was in the fair range. In general, the improvements observed upstream from the confluence were reversed immediately downstream (*e.g*. there were increases in abundance of tolerant dipterans and other non-insect taxa and decreases in numbers of hydropsychid caddisflies and tanytarsini midges). Communities were not strongly indicative of a toxic impact but may reflect additional nutrient enrichment downstream from Crosses Run. Sampling from the mouth of Crosses Run suggested enrichment and degraded water quality conditions.

Mill Creek ICI scores gradually improved downstream and were in the good range at RM 6.9 and 1.6 (36 and 40, respectively). The continued presence of large numbers of blackflies in the lower reaches of the mainstem indicated high background levels of suspended organic material; an additional increase in predominance at RM 1.6 may reflect additional nutrient inputs downstream from Blues Creek.

ICI performance in the lower reaches of Mill Creek approximated that found upstream from Marysville. However, recovery was considered incomplete upstream from the confluence with the Scioto River. In addition to the indications of high nutrient levels manifested in the presence of high numbers of blackflies, scores for mayfly and caddisfly taxa richness on the natural substrates (Qual EPT) were depressed throughout the lower mainstem and did not equal the performance of the RM 28.1 control downstream to RM 1.6. Physical habitat conditions at most mainstem stations as mentioned in the section **Habitat Assessment** were more than adequate to support high quality communities but, with few exceptions, collections reflected degraded or marginal water quality. In addition to Marysville, additional point and nonpoint source inputs downstream may contribute to the depressed conditions.

Town Run

Qualitative sampling from the mouth of Town Run revealed severe water quality problems in Marysville. Only sixteen taxa were collected and most were tolerant varieties often associated with toxic conditions. Physical indications of water quality problems that were observed while sampling this stream included a pungent septic odor, suspended solids in the water column, an oil sheen on the water's surface and deposits of oily muck lining the stream bed.

Crosses Run

The ICI of 4 at RM 2.1 reflected poor-very poor water quality conditions. The oligochaetes, pulmonate snail and midge populations which predominated the sample are often associated with severe organic enrichment and/or toxic impacts. Dense mats of filamentous algae observed in the open ditch may have resulted in extreme diurnal D.O. fluctuations. Also, during the six week sampling period, the grass and rip-rapped banks immediately upstream appeared to have been treated with herbicide to kill weeds and vegetation. Run-off from this activity could potentially impact the resident fauna.

Samples from the mouth of Crosses Run RM (0.1) improved to the fair range (ICI=22 at RM 0.1) but remained well below the WWH criterion. Artificial and natural substrate communities were indicative of significant enrichment, but improvements in some metrics (*eg.* tanytarsini midges, tolerant taxa, Qual EPT) reflected a lessening of the severe impacts observed upstream.

Table 13. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Mill Creek study area, July 10 to September 13, 1990.

Quantitative Evaluation

Stream River Mile	Narrative Evaluation	ICI	No. Quant. Taxa	Relative Density	No. Qual. Taxa	Qual. EPT[b]
Mill Creek						
28.2	V. Good	42	34	554	44	11
19.0	Fair	22*	34	414	34	5
18.6	Fair	18*	29	221	31	5
18.2	Fair	12*	24	489	22	4
18.1	Fair	14*	23	564	20	3
16.9	Fair	20*	26	372	28	5
12.1	Marg. Good	34[ns]	26	753	35	7
11.7	Fair	26*	32	682	29	8
6.9	Good	36	24	1207	41	9
1.6	Good	40	25	663	34	11
Crosses Run						
2.1	Poor	4*	20	159	24	2
0.1	Fair	22*	31	476	33	4
Bokes Creek						
27.5	Fair	30*	27	171	35	10
21.4	Good	42	41	365	39	7
14.8	Good	38	35	326	44	11
5.6	Good	36	32	378	49	9

Qualitative Evaluation

Stream River Mile	Narrative Evaluation	No. Qual. Taxa	Qual. EPTb	Relative Density	Predominant Organisms
Town Run					
0.1	Poor	16	0	Mod.	Midges
BMY Tributary					
3.3	Poor	14	0	Low-Mod.	Midges, dragonflies
2.4	Poor	13	0	High	Scuds, isopods, snails
Blues Creek					
6.2	Fair	39	7	Low-Mod.	Clams
0.6	Good	46	9	Mod-High	Caddisflies, riffle beetles dipterans, mayflies

a 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.

b EPT= total Ephemeroptera (mayflies), Plectoptera (stoneflies) and Trichoptera (caddisflies).

* Significant departure from ecoregion biocriteria (>4 ICI units); poor and very poor results are underlined.

ns Nonsignificant departure from biocriterion (≤4 ICI units)

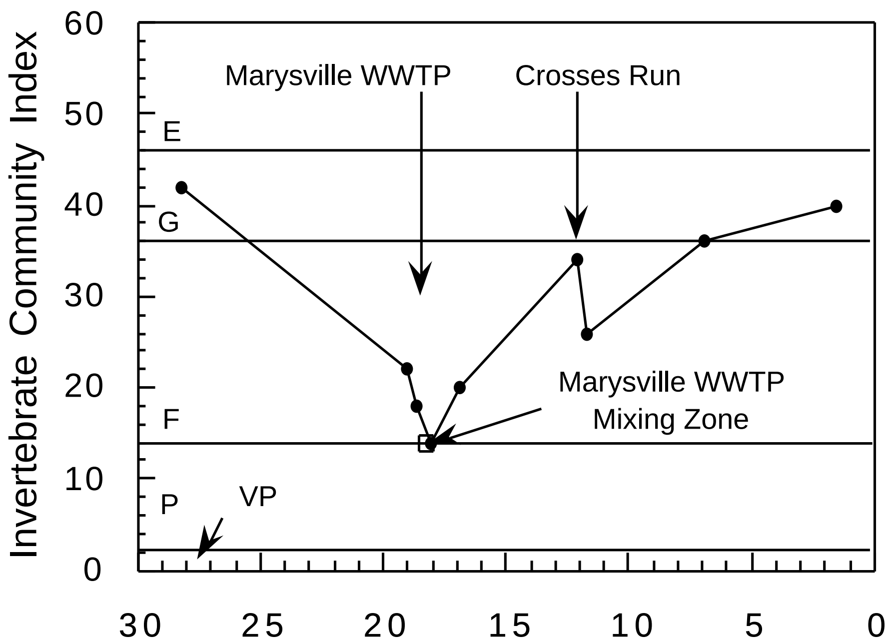


Figure 15. Longitudinal trend of the Invertebrate Community Index (ICI) in the Mill Creek study area, 1990. E denotes exceptional invertebrate communities (meets EWH criterion), G denotes good invertebrate communities (meets WWH criterion), and F, P, and VP denote fair, poor, and very poor invertebrate communities (non-attainment of aquatic life use).

BMY Tributary

Qualitative samples were collected a short distance downstream from the BMY outfall at RM 3.3 and at RM 2.4, immediately upstream from the ODOT rest area WWTP on US 33. The site at RM 3.3 was a channelized, muck and reed lined ditch, while the downstream site was completely overgrown by grass with peat and muck substrates. Communities were poor at both sites and predominated by tolerant varieties. Extremely large numbers of isopods, amphipods, and the pulmonate snail genus Physella at RM 2.4 suggested high nutrient enrichment, but may also be related to the abundance of plant and organic material which predominated the habitats.

Blues Creek

Qualitative samples were collected at RM 6.2 and downstream from the unsewered Village of Ostrander at RM 0.6. The upstream community was impacted by nonpoint agricultural runoff in the form of excessive silt and sediment deposition. Substrates were embedded throughout most of the site and composed of moderately compacted sand, silt and fine gravel. The predominance of silt tolerant burrowing organisms, particularly the fingernail clam Sphaerium sp, was an indicator of the extensive sedimentation.

At RM 0.6, physical habitat conditions and the macroinvertebrate community improved. Substrates were coarse and predominated by rubble with occasional outcroppings of fractured limestone boulders and bedrock. Macroinvertebrates appeared relatively healthy and diverse (46 total taxa; 8 Qualitative EPT taxa), but high population densities were an indication of enriched conditions.

Bokes Creek

Artificial substrate samples were collected at four sites between RM 27.5 and 5.6. All sites were in the good to very good range (*i.e.* ICIs=36-42) with the exception of RM 27.5 which was fair (ICI=30). The nearly intermittent flow conditions at RM 27.5 were considered largely responsible for the lower score. Although some nonpoint influences were probably affecting communities throughout the creek , impacts were comparatively mild when contrasted with qualitative collections and physical habitat observations in the adjacent upper Blues Creek watershed (*i.e.* RM 6.2 in Blues Creek). Sedimentation and substrate embeddedness appeared more severe in Blues Creek with a commensurately poorer community composition.

Trend Analysis-Macroinvertebrates

Mill Creek Mainstem

The 1990 macroinvertebrate data from the Mill Creek mainstem reflects few, if any, improvements when compared to the 1986 survey (Figure 16). At comparable stations, most ICI values were very similar between sampling years and showed nearly identical impact and recovery trends downstream from point and nonpoint source discharges in the Marysville area (Figure 16).

Sampling in 1990 at RM 19.0, immediately upstream from Town Run, indicates that impacts within Marysville's city limits began upstream from Town Run's confluence. As in 1986, community composition measured through town revealed indications of toxicity associated with Town Run, Ray Lewis and Sons (1986) and the Marysville WWTP (1990). In both 1986 and 1990 ICI scores reached the WWH criterion approximately six miles downstream, upstream from the confluence with Crosses Run. Sharp increases in densities of filter-feeding Tanytarsini midges and hydropsychid caddisflies in 1990 were indications of moderate improvements as impacts associated with Marysville lessened downstream.

Both surveys showed declines in ICI values immediately downstream from Crosses Run. The drop in the 1990 ICI was more severe (fair range), resulting in non-attainment of the macroinvertebrates. Community response patterns in 1990 were not strongly indicative of toxic impacts and may indicate additional nutrient enrichment.

Remaining downstream sites in both surveys exceeded WWH criteria but recovery was considered incomplete and not comparable to the high quality communities observed upstream from Marysville. High densities of blackflies, particularly at the RM 1.6 site in 1990, were an indication of significant organic enrichment and less than ideal conditions.

Crosses Run

Previous sampling from Crosses Run at RM 0.8 reflected poor and possibly toxic conditions in 1986 and 1988. Sampling in 1990 also indicated similar, severely impacted conditions in the headwaters (RM 2.1), but improved to the fair range immediately upstream from the confluence with Mill Creek (RM 0.1).

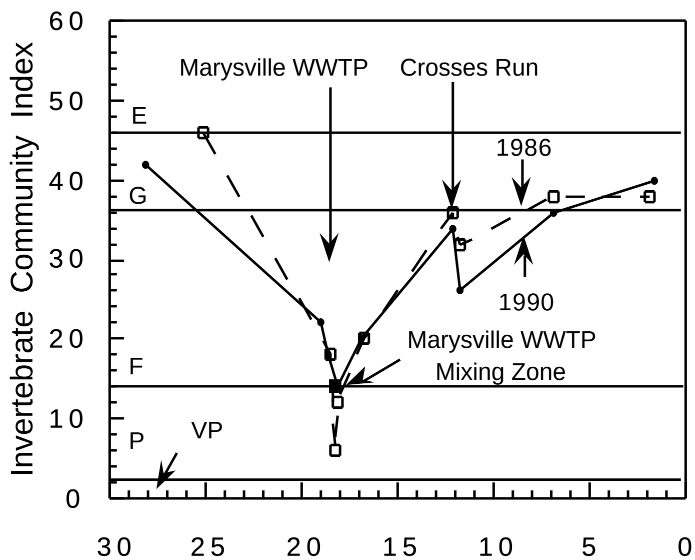


Figure 16. Longitudinal trend of the Invertebrate Community Index (ICI) in the Mill Creek study area during 1986 and 1990. E denotes exceptional invertebrate communities (meets EWH criteria), G denotes good invertebrate communities (meets WWH criteria), and F, P, and VP denote fair, poor, and very poor invertebrate communities (non-attainment of aquatic life use).

Fish Community

Mill Creek Mainstem

Fish communities were sampled at 12 locations from RM 24.8, upstream from Cotton Slash Rd. to RM 1.8, downstream from the confluence with Blues Creek. Narrative evaluations based on IBI and MIwb scores ranged from good (IBI = 38, MIwb = 8.6) at RM 1.8 to poor - fair (IBI = 28, MIwb = 5.3) at RM 16.8 (Table 13, Figure 17).

Upstream from Marysville there were indications of stress in the fish communities in 1990. Although IBI scores exceeded the WWH criterion (IBI = 44) MIwb scores dropped into the fair range (MIwb = 7.4 and 7.7). This portion of the basin is gradually shifting in landuse from agricultural to low density residential as a result of industrial sitings in the area. Upstream from the confluence with Town Run in Marysville (RM 19.0) the MIwb dropped further (MIwb = 6.2) with the IBI also showing a decline. This was manifested in a decrease in relative abundance of fish, an increase in percent of tolerant species and a decline in sucker species. The shift in community composition suggest stress associated with organic enrichment with the location of the site suggesting the source(s) being nonpoint source runoff and combined sewer overflows. One of the last overflow points to be capped in the Marysville combined storm sewer system was the Maple St. overflow. It was upstream from this sampling site and not capped until Sept. 10, 1990. Downstream from Town Run further declines were noted with the community slipping to the fair range resulting mainly from an increase in the percentage of tolerant species and in the incidence of external anomalies. Town Run is a definite source of additional stress to the fish community. The other overflow that was not capped until Sept. 10, 1990 discharged to Mill Creek within this sampling segment.

The effluent from the Marysville WWTP was neither acutely toxic nor immediately stressful to the fish community sampled in the mixing zone. Fish community scores achieved WWH criteria with values higher than upstream. However, a delayed impact associated with the Marysville WWTP was apparent. IBI and MIwb scores declined with downstream distance to the poor - fair range at RM 17.0 with marginal improvements into the fair range at RM 12.2. This pattern is usually characteristic of an organic enrichment impact. Well aerated organic effluents may not be immediately stressful to fish communities until instream decomposition lowers ambient dissolved oxygen concentrations eliminating D.O sensitive species. The greatest impact to the biota typically is associated with the approximate location of the dissolved oxygen sag. Community composition then improves with increases in D.O. with downstream distance.

Crosses Run interrupted this trend of improvement from the impact of the Marysville WWTP. Fish community index scores were essentially identical upstream and downstream from the confluence in 1990. Sampling results from the mouth of Crosses Run revealed very poor to poor conditions. The pattern of improvement with downstream distance interrupted by Crosses Run was re-established at the second site downstream from the confluence with gradual improvement to achievement of WWH criteria at RM 1.8. Despite meeting WWH criteria total recovery was not considered achieved due to the high quality of habitat available in the segment downstream from Crosses Run.

Crosses Run

Although portions of the upstream site (RM 2.1) have been channelized and riprapped and most of the riparian vegetation removed attainment of the MWH criteria (IBI =24) would be expected. The community sampled, however, reflected very poor to poor instream conditions, comprized of headwater and pioneering species (*i.e.,* creek chub, green sunfish, bluntnose minnows, etc.). The IBI at RM 2.1 was only 15 which indicates additional impact beyond habitat limitations and since it is in the very poor range suggests toxicity. It was noted during the survey that the riparian vegetation upstream and along this site had been sprayed with a herbicide. This may partially explain the depressed community. Marginal improvements were noted at the downstream site (RM 0.8); however, index scores still fell in the very poor to poor range. Values this low in locations with perennial flow strongly suggest a toxic impact or a fairly recent fish kill.

BMY Tributary

The BMY Corporation discharged to an intermittent, dredged and maintained drainage ditch not capable of supporting a balanced reproducing WWH fish community (QHEI = 27). Sampling in this tributary was extremely difficult due to the altered state (muck bottom and weeds overgrowing the stream) of the instream habitat and yielded only one juvenile bluegill for the three sites sampled. Despite the limiting nature of the instream and riparian habitat community performance was in the very poor range, strongly indicative of toxicity from the BMY Corporation facility.

To determine the impact of BMY Corp. on Mill Creek,. a comparison was made of sites in Mill Creek upstream and downstream from its confluence. No significant differences were noted. If there was any degradation resulting from the BMY Corporation, it was masked by impacts from upstream Mill Creek sources and any dilution/recovery occurring in the approximately 2.5 mile distance from the BMY tributary confluence to the downstream site.

Blues Creek

This tributary was sampled to evaluate nonpoint source impacts listed for the basin in the 1990 Nonpoint Source Assessment (Ohio EPA 1990b). As mentioned in the section **Habitat Assessment,** habitat impacts resulting from channelization, agricultural run-off and livestock pasturage were evident at the upstream site (RM 6.7). Fish community performance at this site did not achieve the WWH criteria (MIwb = 6.2, IBI = 30), thus reflecting these impacts. Improved habitat, increased gradient, and somewhat different land use resulted in an improved fish community achieving the WWH criteria at the downstream site (RM 0.7).

Bokes Creek

Adjacent to the Mill Creek subbasin, this small stream was also sampled to evaluate nonpoint source impacts listed in the 1990 Nonpoint Source Assessment (Ohio EPA 1990b) and four small point sources. Fish community composition was measured at four sampling locations with narrative evaluations ranging from fair at RM 27.2 (MIwb = 7.5, IBI = 28) to fair - good at RM 5.6 (MIwb = 5.6, IBI = 36). The relatively high mean QHEI of 66.9 for Bokes Creek suggests that the instream and riparian physical habitat is capable of supporting a WWH aquatic community. Although there were physical indications of nonpoint source runoff throughout the basin (*i.e.* moderate silt cover and embeddedness) that may have contributed to the depressed instream community performance, they were not the sole source of stress. High percentages of omnivorous and tolerant species, particularly the bluntnose minnow and creek chub coupled with the loss of intolerant species at the upstream site (RM 27.2) suggest that organic enrichment is an additional source of stress. This observation is supported by the high fecal coliform and fecal streptococcus counts along with high nitrate and elevated ammonia concentrations measured in Bokes Creek. The West Mansfield WWTP, upstream from the study area, may partially account for the depression measured, particularly at the upstream site (RM 27.2). Further declines were noted in the structural composition of the community downstream. A bulk fertilizer facility, Terra International, immediately upstream from the site at RM 21.3 may explain the additional decline. This company was responsible, in 1991, for a fishkill in the Mill Creek basin resulting from the release of anhydrous ammonia. This facility has been closed with the all operations were moved to the Somersville Plant on Bokes Creek. If similar poor house keeping practices, which permitted the chronic problems associated with the Marysville Plant, prevail fish community composition will decline further. Despite a major improvement in instream habitat, the site at RM 13.2, downstream from Powderlick Run and the Daylay and Mad River Egg Farms showed no improvement in community scores. In fact, values upstream were slightly higher than values found downstream from the confluence with Powderlick Run. Water resource quality in Powderlick Run appears to be as poor if not poorer than that in Bokes Creek. Previous chemical sampling has documented high nutrient concentrations in Powderlick Run. If upstream conditions improve Powderlick Run may prevent full achievement of WWH criteria downstream from its confluence.

Trend Analysis - Fish

Mill Creek Mainstem

The 1990 electrofishing results, while showing some similarities with the 1978 and 1986 results, revealed some significant differences suggesting both localized improvements and declines in water resource quality (Figure 18, Tables 14 and 15, Ohio EPA 1980, 1987a).

Statewide over the course of the past 12 years the Ohio EPA has documented substantial improvements in the biological communities of rivers and streams impacted by municipal WWTPs during the last decade (Ohio EPA 1989). This has largely been correlated with improvements in

the treatment of municipal wastewater. However, this was not the pattern observed in the Mill Creek basin.

Upstream from Marysville, biological community scores have registered a modest, but steady decline, from scores fully achieving WWH criteria in 1978, to partial achievement in 1990. The upper portion of the Mill Creek basin is gradually changing from an area that, until recently, was almost entirely agricultural in land use to an area with increased industrial and residential development associated with the construction of the Honda Manufacturing Plants. As this process continues the expectations for instream community performance is one of gradual decline unless plans are developed to minimize the impacts to the riparian zone and runoff from construction and suburban development in this area is closely monitored.

As noted in the 1986 survey combined sewer overflows and industrial dischargers in the area upstream from the Marysville WWTP were a source of impact to the biological communities. Additional sampling locations were sited in this area in 1990 in an attempt to locate the source(s) of this impairment. Sites bracketing Town Run documented impacts to the fish community upstream from Town Run and that a discharger/source to Town Run or in the vicinity of the confluence with Town Run was causing additional impact to the stream.

Upgrades at the Marysville WWTP since the 1986 sampling have resulted in improvements in fish community performance in the area immediately downstream from the outfall (*i.e.* the mixing zone). However a problem still exists in the area downstream from the mixing zone. In 1986 Ray Lewis and Sons was batch discharging plating wastes to Mill Creek immediately upstream from the Marysville WWTP outfall. All of their process wastewaters were tied into the Marysville WWTP in 1988.

Inspection of the longitudinal trends in the Modified Index of Well Being and the Index of Biotic Integrity reveal that the Marysville WWTP mixing zone appeared to be acting as an interruption in the impact(s) caused by sources upstream from the WWTP and in the vicinity of Town Run. The treated effluent supported a fish community improved over what was sampled upstream (at least temporarily). Well oxygenated non-lethal effluent will frequently support a "better" fauna than sites further downstream where eventual bacterial decomposition of organic substances in the effluent results in lowered concentrations of dissolved oxygen. In Mill Creek in 1990, the fish community performance declined at the next two sites downstream from the WWTP following this pattern.

Community performance then improved with increased distance downstream from the Marysville WWTP (RM 18.2). Crosses Run appeared to interrupt recovery in the fish community with community index scores essentially identical upstream and downstream from the confluence in 1990. In 1986 impact from the Marysville WWTP and other sources masked the impact associated

with Crosses Run. Sampling results in Crosses Run showed a decline over what was documented in 1986.

As mentioned previously broadscale improvements in wastewater treatment have resulted in measured improvements in fish community performance in Ohio's rivers and streams over the past decade. This has not been the case in the Mill Creek basin. Negative ADVs for both the IBI and MIwb increased between 1986 and 1990 from 645 (MIwb) and 347 (IBI) to 945 (MIwb) and 646 (IBI) (Table 15). A telling example is the pattern displayed at the downstream site, RM 1.8. Despite possessing habitat easily capable of supporting WWH communities and considerable energy spent improving wastewater treatment at the Marysville WWTP, this site has shown a trend of steady decline since 1978. A suspected cause is the discharges downstream from the Marysville WWTP (Crosses Run , BMY tributary).

<u>Crosses Run</u>

In 1986 poor fish community performance was documented at RM 0.8 in Crosses Run (MIwb = 4.5 and IBI = 23). Sampling in 1990 documented further degradation into the very poor range (MIwb = 1.9 and IBI =

21). Values this low are only encountered in severely toxic situations. As mentioned in the section **Habitat Assessment** the riparian and instream habitat in the segment is fully capable of supporting a WWH fish community. In early 1987 a large fish kill (8047 dead animals counted/estimated) was observed in Mill Creek that extended as far downstream as the mouth. The cause of this fish kill was traced back to a ruptured pipeline from the O.M. Scott Co. complex sited on Crosses Run. Approximately 35,000 gallons of recycle waste water containing ammonia as ammonium hydroxide (1200 mg/l) spilled into an unnamed tributary to Mill Creek. Sediment sampling in the vicinity also revealed contamination of the soils with arsenic, 2,4 - D, atrazine, diazinon and diphenamid. Given three years to recover and an adequate repopulation source (Mill Creek), the fish community sampled in lower Crosses Run would be expected to approach pre-spill levels. This was not the response documented. Fish community index scores were in fact lower than measured in 1986. Prior to the large fish kill/spill documented in 1987 numerous spills were recorded for the O.M. Scott facility. Documented inadequate waste handling practices coupled with elevated to extremely elevated concentrations of pesticides, organic chemicals, and heavy metals in the sediments of Crosses Run and a toxic response in the biological communities suggest that this entity and perhaps other entities discharging to this stream need to be evaluated intensively not only for their effect on water chemistry and instream biota, but also for sediment and ground water contamination.

Table 14. Fish community indices based on electrofishing samples at 22 locations sampled by Ohio EPA in the Mill Creek study area during July -October, 1990.

Stream River Mile	Mean Cum. Species	Mean Rel. Number	Rel. Weight	Modified Index of Well. Being (Iwb)	Index of Biotic Integrity	QHEI[a]	Narrative Evaluation[b]
Mill Creek							
24.8	25	401	97.5	7.4*	44	59	Fair-Good
24.7	28	233	11.8	7.7*	44	59	Fair-Good
19.0	18	222	22.5	6.2*	38^{ns}	71	Fair-Good
18.9 - Town Run Confluence							
18.8	19	281	26.2	6.1*	33*	65	Fair
18.3 - Marysville WWTP Discharge							
18.2	19	999	14.8	8.4	39^{ns}	65	Good
18.1	25	237	14.2	7.5*	39^{ns}	NA	Fair-Good
18.0	22	206	21.3	5.6*	31*	67	Poor-Fair
17.0	16	161	58.9	5.3*	28*	49	Poor-Fair
12.2	20	285	15.0	7.5*	32*	79	Fair
11.8 - Crosses Run Confluence							
11.7	20	374	21.6	7.4*	34*	68	Fair
9.3 - BMY Tributary Confluence							
6.9	18	813	15.9	7.6*	36^{ns}	80	Fair-Good
4.0 - Blues Creek Confluence							
1.8	26	587	23.1	8.6	38^{ns}	74	Good
Tributaries							
Crosses Run							
2.1	4	54	0.7	1.2*	15*		Very Poor-Poor
0.8	9	430	6.8	1.9*	21*	60	Very Poor-Poor
BMY Tributary							
3.4	0	0	0.0	0.0*	12*	27	Very Poor
3.3	1	3	0.0	0.5*	16*	27	Very Poor
2.4	0	0	0.0	NA	12*	27	Very Poor
Blues Creek							
6.7	13	538	11.3	6.2*	30	50	Fair
0.7	23	955	17.3	8.1	40	68	Good

Continued

Table 14 . (Continued)

Stream River Mile	Mean Cum. Species	Mean Rel. Number	Rel. Weight	Modified Index of Well. Being (Iwb)	Index of Biotic Integrity	QHEIa	Narrative Evaluation[b]
Bokes Creek							
27.2	17	902	8.0	7.5*	28*	61	Fair
21.3	13	275	3.8	6.6*	32*	59	Fair
13.2	14	335	3.9	6.3*	32*	83	Fair
5.6	18	356	9.4	5.6*	36[ns]	66	Fair-Good

Eastern Corn Belt Plains WWH Criteria	Wading	Headwaters
Modified Index of Well Being	8.5	-
Index of Biotic Integrity	40	40

NA Headwater site MIwb not applicable.

* Significant departure from applicable biological criterion (more than 4 IBI units; 0.5 Iwb units).

_ Underlined values are in the poor and very poor range.

a QHEI - Qualitative Habitat Evaluation Index.

b Based on MIwb and IBI scores

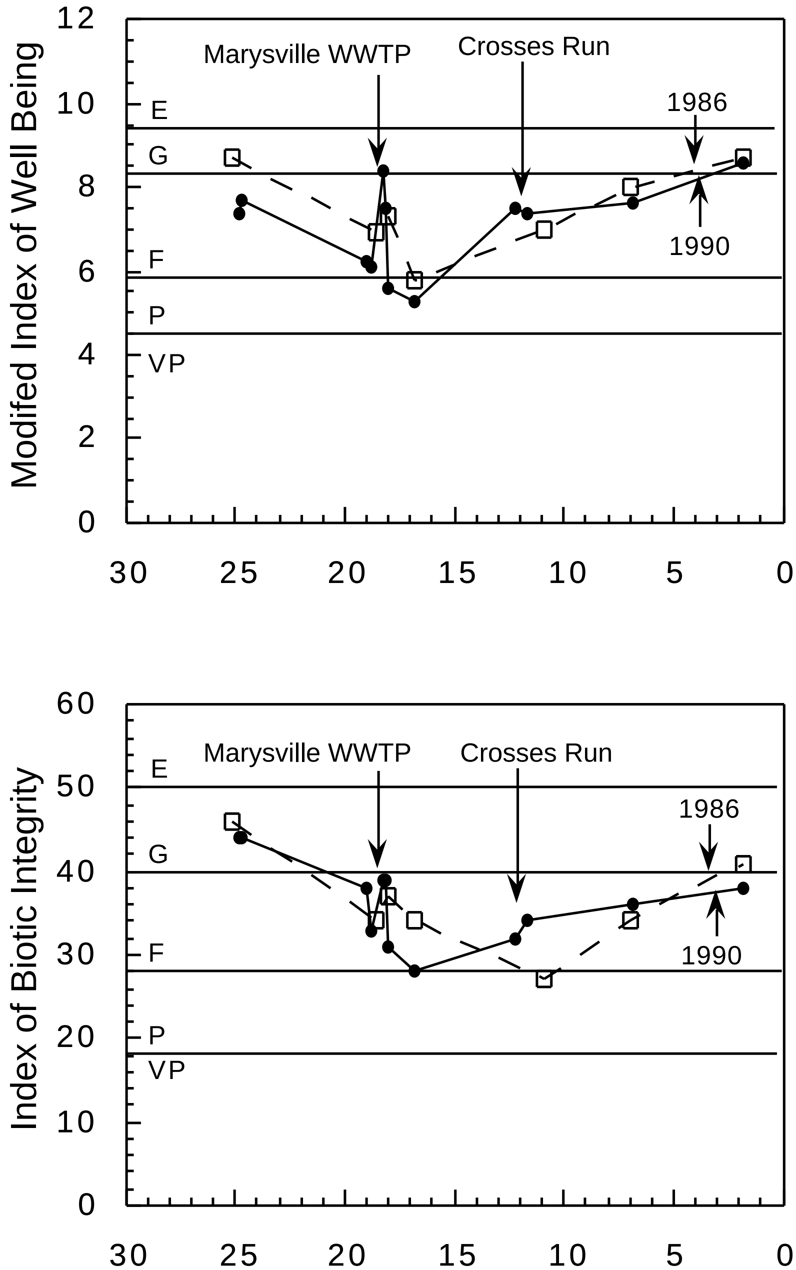


Figure 17. Longitudinal trends in the Index of Biotic Integrity (IBI), the Modified Index of Well-Being (MIwb) in the Mill Creek Study Area, 1990.

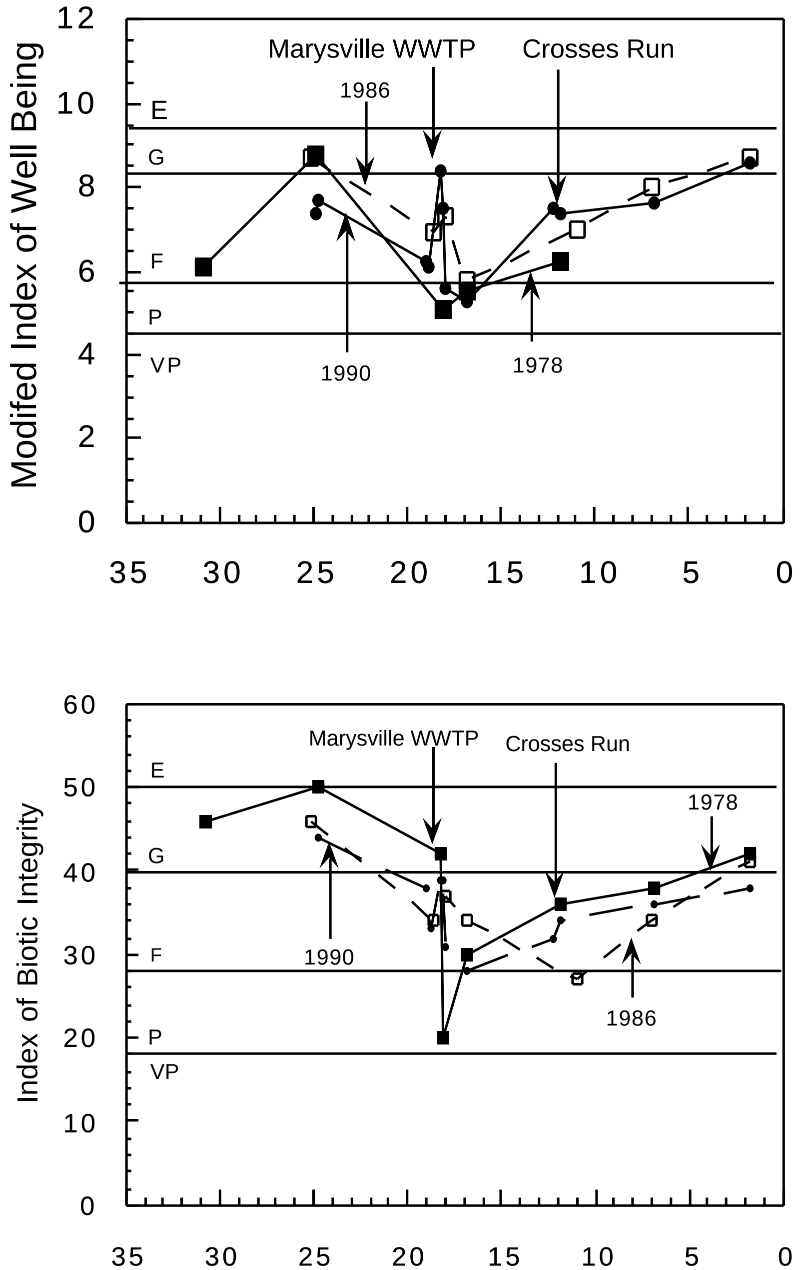


Figure 18. Historical longitudinal trends in the Index of Biotic Integrity (IBI) and the Modified Index of Well-Being based on sampling conducted during 1978, 1986 and 1990.

Table 15. Area of Degradation Value (ADV) statistics for the Mill Creek and Bokes Creek basins, 1978-1990. (Calculated using ecoregion criteria.)

Index	Upper RM	Lower RM	Year	Minimum	Maximum	**ADV**	Poor-VP ADV	Miles: Meeting	Miles: Partial	Miles: Non	Miles: Poor-VP
Mill Creek											
IBI	24.8	1.7	78	30	50	**217**	**0**	0.4	13.3	9.5	7.3
MIwb				NA	NA	NA	NA				
ICI				10	32	**3401**	**57**				
IBI	25.1	1.8	86	27	46	**577**	**0**	6.1	11.3	6.0	0.9
MIwb				5.8	8.7	**645**	**0**				
ICI				12	38	**936**	**0**				
IBI	24.8	1.8	90	28	44	**646**	**0**	1.9	11.6	9.6	0.0
MIwb				5.3	8.6	**945**	**3**				
ICI				14	36	**709**	**0**				
Crosses Run											
IBI	0.8	0.8	86	23	23	**13**	**4**	0.0	0.0	0.1	0.1
MIwb											
ICI											
IBI	2.1	0.8	90	21	21	**90**	**36**	0.0	0.0	0.6	0.6
MIwb											
ICI											
Bokes Creek											
IBI	5.6	27.2	90	28	36	**834**	**0**	0.0	13.6	8.1	0.0
MIwb				5.6	7.5	**1475**	**0**				
ICI				36	42	**0**	**0**				

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List of Appendix Tables

Appendix Tables are available upon written request:

Ohio Environmental Protection Agency
Division of Water Quality Planning and Assessment
1800 WaterMark Drive, P.O. Box 1049
Columbus, Ohio 43266-0149

Table C-1. Results (mean/maximum - minimum)[a] of chemical/physical sampling in the Mill Creek, Bokes Creek study area during July - September, 1990.

Conventional Parameters

STREAM RM	TEMP (C^0)	CONDUCTIVITY (umhos/cm)	DO (mg/l)	BOD-5 DAY (mg/l)	COD (mg/l)	pH (SU)	RESIDUE TOT **NFLT** (mg/l)
28.13	19.1/22.7-13.9	700/759-640	7.0/7.5-5.6	1.3/1.5-1.0	20.6/23.0-20.0	8.0/8.1-7.8	36/97-6
19.00	19.9/22.9-16.2	604/627-581	6.5/7.8-4.9	3.2/4.3-2.1	21.0/23.0-20.0	8.0/8.1-7.8	53/104-25
18.85	19.6/22.0-15.8	584/5900-577	6.6/7.9-4.3*	5.1/6.4-3.7	21.2/23.0-20.0	7.9/8.1-7.8	59/123-22
18.26	22.5/24.5-20.5	1345/1390-1300	7.6/8.3-7.1	4.7/6.6-3.6	33.2/39.0-24.0	7.5/7.5-7.4	6/7-5
18.25	20.7/23.5-17.6	919/977-860	7.0/7.9-5.9	4.9/6.3-3.4	25.2/29.0-21.0	7.6/7.8-7.5	37/92-10
18.14	20.7/23.1-17.5	745/980-320	6.9/8.2-5.2	3.3/6.1-1.6	22.8/32.0-20.0	7.7/8.0-7.5	42/121-9
16.80	20.2/22.8-16.9	863/1110-6.15	6.0/7.6-4.2*	2.8/3.3-2.2	21.8-27.0-20.0	7.7/7.9-7.6	50/121-6
12.17	20.3/23.0-15.3	863/1110-615	6.5/7.1-5.7	1.9/2.0-1.7	23.2/27.0-20.0	7.9/7.9-7.8	40/64-12
11.80	20.6/23.3-16.0	861/1110-611	7.1/7.5-6.2	2.0/2.2-1.8	22.2/26.0-20.0	7.8/7.9-7.8	41/65-10
6.89	18.4/24.0-17.6	852/1120-583	10.9/20.0-7.8	1.9/2.6-1.2	24.0/32.0-20.0	8.0/8.1-8.0	156/666-6
1.80	21.3/25.1-15.5	614/717-510	9.3/10.9-7.5	1.5/1.9-1.0	23.5/29.0-20.0	8.2/8.4-8.0	113/524-8
Town Run							
0.10	18.3/20.7-15.5	700/878-521	7.0/7.8-6.2	7.7/9.3-6.0	24.6/28.0-20.0	7.8/8.0-7.7	33/68-5
Crosses Run							
2.00	18.2/22.6-15.2	1420/1470-1370	9.2/10.4-7.5	2.9/3.3-2.4	24.6/37.0-20.0	8.1/8.1-8.0	5/5-5
0.80	19.5/21.8-17.1	878/1050-705	6.1/7.9-4.7*	6.9/9.3-4.4	26.4/34.0-20.0	7.8/7.9-7.8	7/11-5
BMY Tributary							
3.90	17.3/19.0-14.6	560/560-560	7.8/8.3-7.4	1.3/1.6-1.0	28.0/45.0-20.0	8.0/8.2-7.9	20/27-14
3.80	22.2/25.2-18.3	292/292-292	6.8/7.4-5.9	1.4/1.8-1.0	20.0/20.0-20.0	8.1/8.3-7.9	69/196-18
3.70	21.4/24.0-17.1	718/718-718	8.4/9.5-7.6	2.6/2.7-2.4	35.6/50.0-20.0	7.5/8.0-7.1	11/29-5
3.28	20.0/22.3-16.1	560/560-560	6.0/7.9-4.7*	2.1/3.2-1.0	21.4/27.0/20.0	7.6/7.7-7.4	148/28-5
2.32	18.9/21.5-15.3	458-529-387	5.5/6.3-4.4*	1.2/1.4-1.0	22.3/27.0-20.0	7.7/7.7-7.5	9/12-50
Blues Creek							
6.65	18.9/22.5-13.0	1014/1014-1014.0	6.1/7.0-4.9*	1.9/4.0-1.0	22.0/24.0-20.0	7.6/8.0-7.1	231/1040-12
0.60	20.4/25.0-14.5	955/955-955.0	9.5/15.2-7.2	1.8/4.0-1.0	21.0/22.0-20.0	8.0/8.1-7.8	105/460-6
Bokes Creek							
27.22	18.7/21.5-12.0	705/905-530	6.0/8.0-4.4*	1.9/2.8-1.0	20.0/20.0-20.0	7.9/8.1-7.7	26/44-6
21.29	18.1/23.6-9.1	666/868-496	6.4/8.5-4.2*	1.7/3.2-1.0	23.5/32.0-20.0	7.9/8.1-7.7	23/46-6
14.73	19.4/22.4-13.7	753/1052-483	7.0/7.7-5.8	1.6/3.2-1.0	23.3/24.0-23.0	7.9/8.2-7.6	40/86-12
5.55	19.8/23.2-13.8	733/954-393	6.6/7.8-5.0	1.6/2.5-1.0	20.5/21.0-20.0	7.9/8.0-7.7	44/95-13

(Continued)

Table C-1. (Continued)

NUTRIENTS

STREAM RM	NH-3 TOT (mg/l)	NO2-N TOT (mg/l)	TOT KJEL (mg/l)	NO2 & NO3 N TOT(mg/l)	PHOS TOT (mg/l)
Mill Creek					
28.13	0.08/0.21-0.05	0.05/0.14-0.02	0.7/1.5-0.4	2.97/19.90-0.15	0.09/0.18-0.05
19.00	0.09/0.21-0.05	0.07/0.17-0.03	0.6/1.0-0.4	2.86/9.78-0.24	0.12/0.21-0.08
18.85	0.10/0.20-0.05	0.06/0.12-0.02	0.7/1.0-0.4	2.86/941-0.28	0.22/0.46-0.12
18.26	2.00**/5.64**-0.08	0.11/0.22-0.02	4.0/7.1-1.7	5.46/9.601.92	3.49/4.89-1.37
18.25	1.19/3.44**-0.06	0.09/0.13-0.02	2.5/4.5-1.3	4.49/7.72-2.56	2.02/2.63-0.61
18.14	0.21/0.67-0.05	0.07/0.16-0.02	1.1/1.8-0.5	3.29/9.70-1.02	1.07/1.85-0.05
16.80	0.29/0.53-0.05	0.12/0.17-0.02	1.3/1.6-1.0	4.35/9.75-2.10	1.07/2.68-0.19
12.17	0.07/0.12-0.05	0.06/0.10-0.02	0.9/1.1-0.7	2.95/6.60-1.20	0.79/1.19-0.32
11.80	0.16/0.45-0.05	0.08/0.12-0.04	1.3/2.6-1.0	3.32/6.79-1.64	0.62/1.02-0.20
6.89	0.10/0.26-0.05	0.06/0.14-0.02	1.0/1.3-0.7	2.69/4.41-0.92	0.81/1.13-0.30
1.80	0.07/0.22-0.05	0.04/0.08-0.02	0.8/1.1-0.6	2.89/7.12-0.72	0.40/0.69-0.19
Town Run					
0.10	0.31/0.41-0.15	0.08/0.12-0.04	0.9/1.2-0.4	1.84/5.52-0.59	0.20/0.30-0.11
Crosses Run					
2.0	1.90**/4.16**-0.05	0.60/0.83-0.18	3.0/5.5-0.4	6.90/13.7-1.61	0.20/0.29-0.07
0.80	2.78/7.76-0.05	0.56/0.83-0.18	10.0/32.1-0.6	7.61/8.93-4.87	0.47/0.68-0.26
BMY Tributary					
3.90	0.05/0.05-0.05	0.05/0.07-0.02	0.9/1.3-0.4	8.27/14.5-4.18	0.11/0.15-0.06
3.80	0.07/0.09-0.05	0.29/0.78-0.09	0.6/0.6-0.5	4.30/6.35-1.94	0.06/0.08-0.05
3.70	3.48**/7.80**-0.52	0.11/0.17-0.03	4.6/8.4-1.3	23.1/37.6-4.08	3.02/4.17-1.44
3.28	0.22/0.87-0.05	0.31/0.59-0.02	0.9/1.7-0.6	11.15/19.3-5.66	0.65/1.51-0.14
2.32	0.05/0.05-0.05	0.03/0.06-0.02	0.7/0.9-0.6	3.84/6.70-0.95	0.30/1.04-0.11
Blues Creek					
6.65	0.13/0.41-0.05	0.06/0.18-0.02	0.8/1.2-0.5	3.40/14.20-0.10	0.16/0.36-0.09
0.60	0.14/0.31-0.05	0.05/0.10-0.03	0.7/1.1-0.5	3.52/14.10-0.32	0.13/0.20-0.08
Bokes Creek					
27.22	0.8/0.12-0.05	0.06/0.08-0.03	0.8/1.0-0.4	3.11/9.20-0.25	0.22/0.31-0.13
21.29	0.30/1.35**-0.05	0.08/0.15-0.03	1.4/3.0-0.5	3.59/11.20-0.62	0.20/0.34-0.11
14.73	0.07/0.16-0.05	0.05/0.09-0.02	0.8/1.1-0.5	3.65/12.70-0.52	0.19/0.29-0.12
5.55	0.7/0.11-0.05	0.05/0.09-0.03	0.8/1.1-0.6	2.42/7.07-0.71	0.19/0.27-01.2

(Continued)

Table C-1. (Continued)

Metals

STREAM RM	Hardness (mg/l)	Ca-TOT (mg/l)	Mg-TOT (mg/l)	Fe-TOT (ug/l)	Cd-TOT (ug/l)	Cr-TOT (ug/l)
Mill Creek						
28.13	329.8/391.0-195.0	75.4/85.0-50.0	34.4/44.0-17.0	485/530-440	>0.2/0.3->0.2	>30/>30->30
19.00	317.8/474.0/-160.0	73.2/104.0-41.0	32.8/52.0-14.0	1250[b]/1380[b]-1120[b]	>0.2/>0.2->0.2	>30/>30->30
18.85	274.0/403.0-160.0	65.2/89.0-41.0	27.0/44.0-14.0	1455[b]/1530[b]-1380[b]	>0.2/>0.2->0.2	>30/>30->30
18.26	213.8/235.0/190.0	54.6/61.0-48.0	18.8/20.0-17.0	210/230-190	>0.2/>0.2->0.2	>30/>30->30
18.25	249.8/309.0-174.0	60.8/71.0-45.0	23.8/32.0-15.0	755/900-610	>0.2/>0.2->0.2	>30/>30->30
18.14	262.0/338.0-162.0	63.2/75.0-42.0	25.3/36.0-14.0	1320[b]/1720[b]-710	>0.2/>0.2->0.2	>30/>30->30
16.80	260.8/349.0-160.0	63.6/79.0-41.0	24.8/37.0-14.0	1470[b]/1910[b]-1030[b]	>0.2/>0.2->0.2	>30/>30->30
12.17	316.6/365.0-236.0	77.2/87.0-64.0	30.2/37.0-19.0	1680[b]/1730[b]-1630[b]	>0.2/>0.2->0.2	>30/>30->30
11.804	340.3/379.0-258.0	77.6/89.0- 64.0	33.5/38.0-22.0	1560[b]/1580[b]-1540[b]	>0.2/>0.2->0.2	>30/>30->30
6.89	315.4/386.0/219.0	76.2/92.0-53.0	30.4/38.0-21.0	1335[b]/1750[b]-920	>0.2/0.3->0.2	>30/>30->30
1.80	317.3/415.0-216.0	77.2/97.0-57.0	30.3/42.0-18.0	585/6100-560	>0.2/>0.2->0.2	>30/>30->30
Town Run						
0.10	297.2/524.0-164.0	75.8/124.0-46.0	26.2/52.0-12.0	2070[b]/2820[b]-1320[b]	>0.2/0.3->0.2	>30/>30->30
Crosses Run						
2.00	687.6/887.0-351.0	167.8/210.0-96.0	65.2/88.0-27.0	280/280-280	>0.2/>0.2->0.2	>30/>30->30
0.80	423.2/694.0-265.0	107.8/169.0-73.0	37.4/66.0-20.0	545/800-290	>0.2/>0.2->0.2	>30/>30->30
BMY Tributary						
3.90	284.0/312.0-246.0	76.3/82.0-69.0	22.8/26.0-18.0	2065[b]0/2330[b]-1800[b]	>0.2/>0.2->0.2	>30/>30->30
3.80	141.2/153.0-122.0	45.0/48.0-39.0	7.0/8.0-6.0	5050[c]/5970[c]-4130[b]	>0.2/0.3->0.2	>30/>30->30
3.70	319.3/597.0-196.0	70.0/84.0-56.0	33.0/94.0-10.0	140/160-120	8.6/14.6-2.0	>30/>30->30
3.2.8	198.8/223.0-175.0	59.8/68.0-52.0	12.0/13.0-11.0	765.0/800.0-730.0	1.0/3.0-0.2	>30/>30->30
2.32	206.8/232.0-173.0	60.4/68.0-51.0	13.6/15.0-11.0	935/1320[b]-550	>0.2/0.3->0.2	>30/>30->30
Blues Creek						
6.65	423.0/423.0-423.0	97.0/97.0-97.0	44.0/44.0-44.0	1020[b]/1020[b]-1020[b]	>0.2/>0.2->0.2	>30/>30->30
0.60	510.0/510.0-510.0	117.0/117.0-117.0	53.0/53.0-53.0	600/600-600	>0.2/>0.2->0.2	>30/>30->30
Bokes Creek						
27.22	306.0/306.0-306.0	73.0/73.0-73.0	30.0/30.0-30.0	700/700-700	>0.2/>0.2->0.2	>30/>30->30
21.29	418.0/418.0-418.0	95.0/95.0-95.0	44.0/44.0-44.0	930/930-930	>0.2/>0.2->0.2	>30/>30->30
14.73	384.0/384.0/384.0	88.0/88.0-88.0	40.0/40.0-40.0	920/920-920	>0.2/>0.2->0.2	>30/>30->30
5.55	437.0/437.0-437.0	96.0/96.0-96.0	48.0/48.0-48.0	920/920-920	>0.2/>0.2->0.2	>30/>30->30

(Continued)

Table C-1. (Continued)

Metals

STREAM RM	As-TOT (ug/l)	Cu-TOT (ug/l)	Pb-TOT (ug/l)	Ni-TOT (ug/l)	Zn-TOT (ug/l)
Mill Creek					
28.13	>2.0/>2.0->2.0	>10.0/>10.0->10.0	5.7/2.0-10.0	>40/>40->40	32.5/45.0->10.0
19.00	>2.0/>2.0->2.0	>10.0/>10.0->10.0	3.2/8.0->2.0	>40/>40->40	19.0/35.0->10.0
18.85	2.3/3.0->2.0	11.0/15.0->10.0	5.4/16.0->2.0	>40/>40->40	199.2/900.0->10.0
18.26	2.3/3.0->2.0	>10.0/>10.0->10.0	11.6/24.0->2.0	56.0/100.0->40.0	84.4/120.0-35.0
18.25	>2.0/>2.0->2.0	>10.0/>10.0->10.0	6.8/13.0->2.0	44.0/60.0->40.0	45.0/60.0-15.0
18.14	>2.0/>2.0->2.0	>10.0/>10.0->10.0	6.4/10.0->2.0	>40/>40->40	30.0/45.0->10.0
16.80	>2.0/>2.0->2.0	>10.0/>10.0->10.0	4.6/9.0->2.0	>40/>40->40	33.4/65.0->10.0
12.17	>2.0/>2.0->2.0	>10.0/>10.0->0.0	7.6/28.0->2.0	>40/>40->40	26.0/45.0-15.0
11.804	2.3/3.0->2.0	>10.0/>10.0->10.0	2.4/4.0->2.0	>40/>40->40	12.8/15.0->10.0
6.89	4.3/10.0->2.0	12.0/20.0->10.0	7.2/24.0->2.0	>40/>40->40	42.0/95.0->10.0
1.80	3.0/5.0->2.0	10.8/15.0->10.0	4.3/15.0->2.0	>40/>40->40	26.0/72.0->10.0
Town Run					
0.10	2.3/3.0->2.0	16.0/30.0->10.0	7.4/16.0->2.0	>40/>40->40	40.4/85.0->10.0
Crosses Run					
2.00	>2.0/>2.0->2.0	>10.0/>10.0->10.0	3.4/9.0->2.0	>40/>40->40	15.8/30.0->10.0
0.80	2.8/3.0->2.0	>10.0/>10.0->10.0	>2.0/>2.0->2.0	>40/>40->40	15.0/20.0->10.0
BMY Tributary					
3.90	>2.0/>2.0->2.0	>10.0/>10.0->10.0	2.3/3.0->2.0	>40/>40->40	17.5/40.0->10.0
3.80	2.3/3.0->2.0	>10.0/>10.0->10.0	2.2/3.0->2.0	>40/>40->40	15.6/20.0->10.0
3.70	>2.0/>2.0->2.0	3342.0/7450.0-250.0	>2.0/>2.0->2.0	>40/>40->40	69.0/170.0->10.0
3.2.8	>2.0/>2.0->2.0	245.0/800.0-20.0	>2.0/>2.0->2.0	>40/>40->40	16.0/30.0->10.0
2.32	>2.0/>2.0->2.0	>10.0/>10.0->10.0	>2.0/>2.0->2.0	>40/>40->40	>10.0/>10.0->10.0
Blues Creek					
6.65	---	>10.0/>10.0->10.0	>2.0/>2.0->2.0	>40/>40->40	>10.0/>10.0->10.0
0.60	---	>10.0/>10.0->10.0	>2.0/>2.0->2.0	>40/>40->40	>10.0/>10.0->10.0
Bokes Creek					
27.22		>10.0/>10.0->10.0	>2.0/>2.0->2.0	>40/>40->40	40.0/40.0-40.0
21.29		>10.0/>10.0->10.0	>2.0/>2.0->2.0	>40/>40->40	20.0/20.0-20.0
14.73		>10.0/>10.0->10.0	>2.0/>2.0->2.0	>40/>40->40	>10.0/>10.0->10.0
5.55		>10.0/>10.0->10.0	>2.0/>2.0->2.0	>40/>40->40	>10.0/>10.0->10.0

(Continued)

Table C-1. (Continued)

MISCELLANEOUS

STREAM	Fecal Coliform (#/100 ml)	Fecal Strep. (#/100 ml)	Chloride (mg/l)
Mill Creek			
28.13	2460/10000-125	12389/>60000-55	20.2/28.0-13.0
19.00	16660/>60000-2000	19012/>60000-440	22.2/31.0-13.0
18.85	22000/>60000-4000	18016/>60000-780	23.6/33.0-12.0
18.26	52/130-10	152/640-10	132.8/170.0-71.0
18.25	15662/>60000-50	12326/>60000-10	76.4/107.0-31.0
18.14	7270/17000-410	9818>60000-200	56.0/83.0-12.0
16.80	17190/>60000-270	12549/>60000-10	56.0/108.0-14.0
12.17	2640/8000-700	12461/>60000-140	66.2/119.0-21.0
11.80	2700/9000-740	1337/>60000-140	56.6/81.0-21.0
6.89	4538/17000-270	12369/>60000-70	69.4/105.0-22.0
1.80	9123/52000-100	20103/>60000-10	51.3/83.0-16.0
Town Run			
0.10	26622/>60000-10	20402/>60000-10	37.8/50.0-16.0
Crosses Run			
2.00	1854/4900-110	12377/>60000-80	41.4/52.0-30.0
0.80	1677/5600-440	12582/>60000-260	36.2/46.0-26.0
BMY Tributary			
3.90	15912/55000-1400	17710/>60000-1300	34.8/59.0-13.0
3.80	1250/3100-190	12188/>60000-50	5.6/8.0-5.0
3.70	22/60-10	1208/>60000-10	44.8/76.0-10.0
3.2.8	1430/6000-80	12623/>60000-420	22.0/34.0-10.0
2.32	316/680-150	12196/>60000-120	20.4/32.0-11.0
Blues Creek			
6.65	6278/29000-387	12188/>60000-180	38.2/48.0-13.0
0.60	7488/32000-1060	12149/>60000-10	38.2/55.0-15.0
Bokes Creek			
27.22	20872/>60000-500	14467/>60000-200	30.8/47.0-19.0
21.29	4135/17000-310	9188/45000-90	32.2/47.0-17.0
14.73	682/1080-270	11320/>60000-160	57.8-111.0-19.0
5.55	1582/3100-330	16316/>60000-140	66.2/110.0-15.0

(Continued)

Table C-1. (Continued)

a Means calculated using detection limits as the minimum value where reported minimum was less than detection limits.

b Denotes exceedences of outside mixing zone primary contact recreation standard of 1000 colonies/100ml.

c Denotes exceedences of outside mixing zone secondary contact recreation standard of 5000 colonies/100ml.

* Denotes exceedence of numerical criteria for prevention of chronic toxicity.

** Denotes exceedence of numerical criteria for prevention of acute toxicity.