Assessment of the Impacts of the AK Steel Middletown Facilities in the Dicks Creek Watershed and the Great Miami River mainstem: 1980 - 1998

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INTRODUCTION

This assessment was prepared based on the results of water quality and biological monitoring performed by Ohio EPA and EA Engineering, Science, and Technology ("EA Science") between 1980 and 1998. The Ohio EPA monitoring in 1980, 1987, 1989, and 1995 was performed as part of the Five-Year Basin Approach to Monitoring and Assessment which is a statewide, rotating basin assessment process. This work included the integrated assessment of chemical, physical, and biological monitoring data and information primarily for the purpose of assessing status and trends and associated causes and sources of impairments found in the targeted waterbodies. Ohio EPA also performed follow-up chemical/physical sampling in 1997 and 1999, primarily to confirm the presence of previously identified contamination by polychlorinated biphenyls (PCBs). Those results are available elsewhere. EA Science performed biological and water quality monitoring in 1996 and 1998 at the request of AK Steel.

The most recent, comprehensive assessment produced by Ohio EPA for this area was based on the results of sampling conducted in 1995 with trend analyses comparing results from previous years. This information is contained in the report entitled *Biological and Water Quality Study of the Middle to Lower Great Miami River and Selected Tributaries, 1995* (Ohio EPA Technical Report MAS/1996-12-8; Ohio EPA 1997). This report makes no attempt to replace that assessment. However, data collected since 1980 is summarized here in an effort to update the 1995 assessment, include biological data collected since 1995, and determine if any meaningful changes in environmental quality indicators or status of aquatic life uses has taken place since.

METHODS AND PROCEDURES

One purpose of this report is to present an integrated analysis and assessment of all relevant information primarily related to the status of designated aquatic life uses in Dicks Creek and the mainstem Great Miami River that is influenced by the AK 011 outfall. The organization of this assessment generally follows the process used by Ohio EPA in producing biological and water quality reports and similar watershed assessments. Ohio EPA relies on an integrated indicators

approach in assessing the status of aquatic life uses and assigning associated causes and sources of any threats or impairments. The process by which that is accomplished is summarized in the following subsections.

What is a Biological and Water Quality Survey?

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year Ohio EPA conducts biosurveys in 3-4 watershed areas and numerous segment or site-specific different study areas for an aggregate total of 450-500 sampling sites statewide.

Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives:

1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained;

2) determine if use designations assigned to a given water body are appropriate and attainable; and,

3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices.

The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns, are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (*e.g.*, NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1]), and are eventually incorporated into Water Quality Permit Support Documents (WQPSDs), State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, the Ohio Water Resource Inventory (305[b] report), and more recently the development of Total Maximum Daily Loads (TMDL).

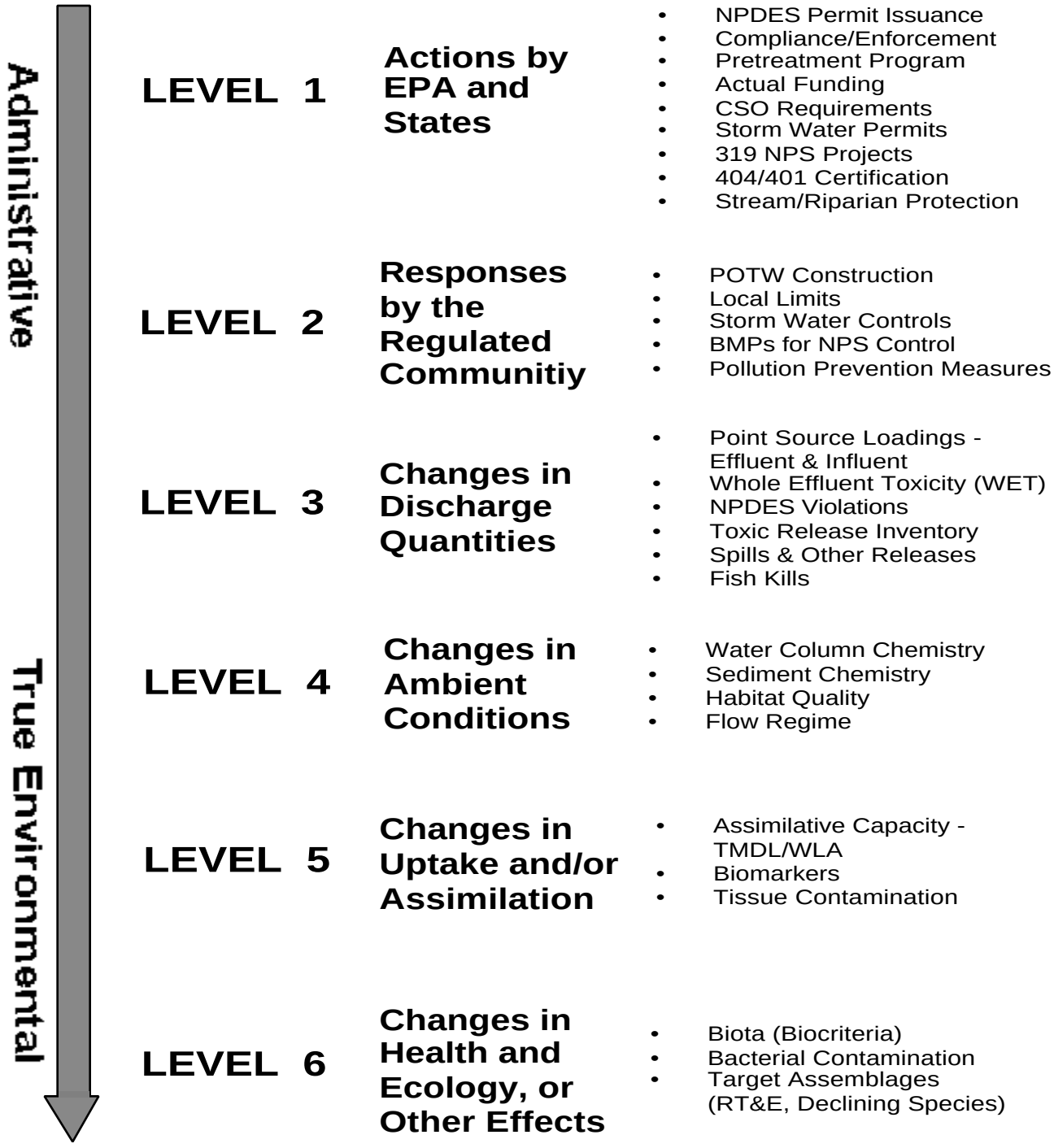

Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA (1995).

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators comprised of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach is outlined in Figure 1 and includes a hierarchical continuum from administrative to true environmental indicators. The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health, ecology, or other effects (ecological condition). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental "results" (level 6).

Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. *Stressor* indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. *Exposure* indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. *Response* indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio's biological criteria. Other response indicators could include target assemblages, *i.e.*, rare, threatened, endangered, special status, and declining species or bacterial levels which serve as surrogates for the recreational uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators *within* the roles which are most appropriate for each.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Ohio Water Resource Inventory (305[b] report), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Uses

The Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) consist of designated uses and chemical, physical, and biological criteria designed to represent measurable properties of the environment that are consistent with the goals specified by each use designation. Use designations consist of two broad groups, aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in Ohio's rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protecting for aquatic life generally results in water quality suitable for all uses. The five different aquatic life uses currently defined in the Ohio WQS are described as follows:

1) *Warmwater Habitat (WWH)* - this use designation defines the "typical" warmwater assemblage of aquatic organisms for Ohio rivers and streams; *this use represents the principal restoration target for the majority of water resource management efforts in Ohio.*

2) *Exceptional Warmwater Habitat (EWH)* - this use designation is reserved for waters which support "unusual and exceptional" assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (*i.e.,* declining species); *this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.*

3) *Coldwater Habitat (CWH)* - this use is intended for waters which support assemblages of cold water organisms and/or those which are stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic "runs" of salmonids during the spring, summer, and/or fall.

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned and permitted by state or federal law;* the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 mi.^{2} drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include

small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.*, true ephemeral streams), or other irretrievably altered waterways.

Chemical, physical, and/or biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such the system of use designations employed in the Ohio WQS constitutes a "tiered" approach in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, temperature, and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different use designations.

Determining Aquatic Life Use Attainment Status

Use attainment status is a term which describes the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-14). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices which include the Index of Biotic Integrity (IBI) and modified Index of Well-Being (MIwb), which indicate the response of the fish community, and the Invertebrate Community Index (ICI), which indicates the response of the macroinvertebrate community. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch *et al.* (1984). The ICI was developed by Ohio EPA (1987b) and further described by DeShon (1995). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information from the Wabash River (Gammon 1976; Gammon *et al.* 1981). Numerical endpoints for each index are stratified by ecoregion, use designation, and stream or river size.

Performance expectations for the principal aquatic life uses in the Ohio WQS (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 1987). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Attainment of the aquatic life use is full if all three indices (or those available) meet the applicable biocriteria, partial if at least one of the indices does not attain and performance at least fair, and non-attainment if all indices fail to attain or any index indicates poor or very poor performance. Partial and non-attainment

indicate that the receiving water is impaired and does not meet the designated use criteria specified by the Ohio WQS. An aquatic life use attainment table is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.*, full, partial, or non-attainment), the Qualitative Habitat Evaluation Index (QHEI), and comments and observations for each sampling location.

Area of Degradation Value (ADV)

An Area Of Degradation Value (ADV; Yoder and Rankin 1995) was calculated for the study area based on the longitudinal performance of the biological community indices. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, or ICI) departs from the applicable biocriterion or the upstream level of performance (Figure 2). The "magnitude" of impact refers to the vertical departure of each index below the biocriterion or the upstream level of performance. The total ADV is represented by the area beneath the biocriterion (or upstream level) when the results for each index are plotted against river mile. The results are expressed as ADV/mile to normalize comparisons between segments, sampling years, and other streams and rivers.

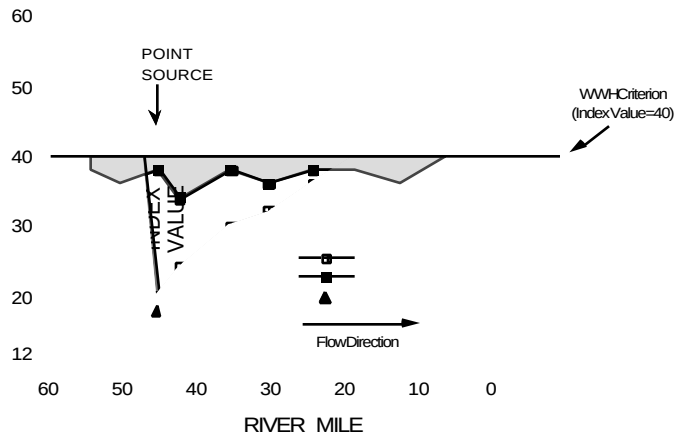

Figure 2. Graphic illustration of the Area of Degradation Value (ADV) based on the ecoregion biocriterion (WWH in this example). The index value trend line indicated by the unfilled boxes and solid shading (area of departure) represents a typical response to a point source impact (mixing zone appears as a solid triangle); the filled boxes and dashed shading (area of departure) represent a typical response to a nonpoint source or combined sewer overflow impact. The blended shading represents the overlapping impact of the point and nonpoint sources.

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are the principal arbiter of aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria in the role of principal arbiter within a weight of evidence framework has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991;

Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators with linkages to the biosurvey data being based on previous experience with strata of analogous situations and impacts. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified. The process is similar to making a medical diagnosis in which a doctor relies on multiple lines of evidence concerning patient health. Such diagnoses are based on previous research which experimentally or statistical links symptoms and test results to specific diseases or pathologies. Thus a doctor relies on previous experiences in interpreting symptoms (*i.e.*, multiple lines from test results) to establish a diagnosis, potential causes and/or sources of the malady, a prognosis, and a strategy for alleviating the symptoms of the disease or condition. As in medical science, where the ultimate arbiter of success is the eventual recovery and well-being of the patient, the ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem "health" compared to human patient "health" (Suter 1993) we are here referring to the process for evaluating biological integrity and causes/sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

ANALYSIS OF RESULTS

The sources of data and information relied on for this assessment are principally from two sources: 1) chemical, physical, and biological data collected by Ohio EPA in 1987 and 1995 in Dicks Creek, and in 1980, 1989, and 1995 in the Great Miami River mainstem; and, 2) the 1998 assessment by EA Science which included chemical/physical and biological data in both Dicks Creek and the Great Miami River mainstem.

Monitoring and Assessment Results: 1980-1998

The results of the biological and water quality assessments of the Dicks Creek watershed and mainstem Great Miami River by Ohio EPA and EA Science is summarized in the following:

1) aquatic life use attainment tables for the Dicks Creek watershed and Elk Creek based on sampling by Ohio EPA (Tables 1 and 2); a use attainment table for the Dicks Creek watershed based on sampling conducted by EA Science in 1998 (Table 3); a use attainment table for the Great Miami River mainstem based on Ohio EPA sampling in 1980, 1989, and 1995 (Table 4); and, a use attainment table for the Great Miami River mainstem based on EA

Science sampling in 1998 (Table 5).

2) plots of the Invertebrate Community Index (ICI; Figure 3), Index of Biotic Integrity (IBI; Figure 4), and modified Index of Well-Being (MIwb; Figure 5) by river mile as an "upstream/downstream" longitudinal assessment of Dicks Creek;

3) an assessment of quantitative changes in aquatic life use attainment status and departures from the biological criteria utilizing the area of degradation value (ADV) and allied concepts and statistics (Figures 6,7, and 8);

4) an analysis of the response of the biological community using the biological response signature concept (Tables 6 and 7); and,

5) a matrix of environmental indicators (Figure 9) arranged in accordance with the role of each as described in the hierarchy of environmental indicators (see Figure 1 and attending discussion).

The results of the 1998 biological sampling conducted by EA Science is incorporated for comparison purposes in the IBI, MIwb, and ICI figures (Figures 3 through 5), as part of the ADV analysis (Figures 6, 7, and 8), and the biological response signatures assessment (Tables 6 and 7). These results were also included for the purpose of determining if any changes have taken place since the most recent Ohio EPA biological and water quality assessment in 1995.

Aquatic Life Use Attainment Status

The principal method by which the status of designated aquatic life uses is determined is by constructing a use attainment table. Such a table communicates the attainment status of a sampling location as full, partial or non-attainment of the applicable use designation. Also included are the index values for the indices on which the biological criteria are based, an indication of whether or not the index value meets, exceeds, or falls below the applicable biocriterion, and an indication if the value represents poor or very poor quality. The Qualitative Habitat Evaluation Index (QHEI) score is included along with a brief description of the site, generally indicating the location of the site in proximity to major stressors or other features of the site. The table also demonstrates the changes, if any, in use attainment status in an upstream to downstream direction and is useful for determining the aggregate miles of full, partial, and non-attainment over a reach of river or stream.

1987 Ohio EPA Dicks Creek Results

The results of the 1987 Ohio EPA biological assessment were used initially to revise the aquatic life uses applicable to Dicks Creek and the North Branch. The Modified Warmwater Habitat (MWH) was recommended and adopted for the segment of Dicks Creek between Cincinnati-

Dayton Rd. (RM 5.4) downstream to Yankee Rd. (RM 2.4) and the North Branch between Breiel Blvd. (RM 1.0) and the mouth (RM 0.0). All other segments are designated as Warmwater Habitat (WWH). These designations then determine which biological criteria apply for the purpose of determining aquatic life use attainment status.

The attainment status in 1987 was full at RM 5.5 in the WWH segment upstream from Cincinnati-Dayton Rd. and at RM 4.6/4.7[1] in the MWH segment downstream from the North Branch and the AK 004 outfall (Table 1). Use attainment status was also full for the MWH use in the North Branch downstream from the AK 004 outfall, but partial upstream due to the failure of the ICI to meet the applicable biocriterion. Beginning at the site downstream from Shaker Creek (RM 4.2/4.1) the use attainment status declined to partial and then to non-attainment downstream from the AK 003 outfall (RM 3.4/3.6) and remaining that way through the remainder of Dicks Creek. With the exception of the two most downstream sites, the principal determinant of the non-attainment was the poor performance of the macroinvertebrate community. However, evidence of acutely toxic conditions to the fish community was also manifest in the results at RM 2.5 and in the direct observations made by field personnel.

Two tributaries, Shaker Creek and Millers Creek, were also assessed and all except the upstream site on Shaker Creek were in non-attainment. The fish and macroinvertebrate communities both performed in the poor or very poor ranges and this was attributed to various stressors including domestic wastes from the Lebanon Correctional Institution and two small industries discharging to Millers Creek (Table 1). A nearby regional reference site was included for comparison purposes and to highlight regional potential. Elk Creek performed at exceptional levels and this led to a recommendation for a revision of the use to Exceptional Warmwater Habitat (EWH).

1995 Ohio EPA Dicks Creek Results

The attainment status in Dicks Creek in 1995 was non-attainment throughout the WWH and MWH segments and at both sites in the North Branch (Table 2). This was driven by poor and very poor macroinvertebrate community results upstream from Shaker Creek and the AK 015 outfall. The fish community was in full attainment of MWH both in and downstream from the North Branch. Macroinvertebrates continued to reflect poor quality downstream from the AK 015 outfall to RM 1.7 (Table 2). The fish community failed to meet the MWH criteria during the second sampling pass downstream from the AK 003 outfall to the mouth. Poor and very

[1] Linked river miles for fish/macroinvertebrate sampling locations.

Table 1. Aquatic life use attainment status for applicable use designations in Dicks Creek, North Branch Dicks Creek, Shaker Creek, Millers Creek, and Elk Creek based on sampling conducted by Ohio EPA during 1987.

RIVER MILE Fish/Invert.	IBI	MIwb	ICI[a]	QHEI	Attainment Status[b]	Comment
Dicks Creek (1987)						
			E. Corn Belt Plain - WWH Use Designation (Existing)			
5.5/ --	30	NA	--	77.0	[FULL]	ust. Cincinnati-Dayton Rd.
			E. Corn Belt Plain - MWH Use Designation (Existing)			
4.6/4.7	39	NA	30	53.0	FULL	dst. N. Branch, AK 004
4.2/4.1	29	6.5	16*	43.0	PARTIAL	dst. Shaker Cr. & AK 015
3.4/3.6	31	7.7	4*	41.0	**NON**	dst. AK 003
2.7/2.7	27	6.6	10*	32.0	**NON**	dst. AK 002
			E. Corn Belt Plain - WWH Use Designation (Existing)			
2.5 /1.7	21*	5.3*	8*	32.0	[**NON**]	dst. AK Landfill trib.
0.2/0.2	31*	7.6*	22*	85.0	**NON**	ust. mouth
N. Br. Dicks Creek (1987)						
			E. Corn Belt Plain - MWH Use Designation (Existing)			
1.1/1.0	35	NA	18*	52.0	PARTIAL	ust. AK 004
0.1/0.1	43	NA	F	41.0	FULL	dst. AK 004
Shaker Creek (1987)						
			E. Corn Belt Plain - WWH Use Designation (Existing)			
5.9/ --	36[ns]	NA	--	69.0	[FULL]	ust. LCI
2.8/ --	20*	NA	--	44.0	**NON**	dst. LCI
1.1/1.0	17*	NA	P*	--	**NON**	ust. Millers Cr.
0.3/0.7	25*	3.7*	F*	44.0	**NON**	dst. Millers Cr.
Millers Creek (1987)						
			E. Corn Belt Plain - WWH Use Designation (Existing)			
0.3/0.1	20*	NA	F*	45.0	**NON**	dst. Worthington Steel
Elk Creek (1987)						
			E. Corn Belt Plain - EWH Use Designation (Recommended)			
3.7/3.7	50	10.4	--	92.0	[FULL]	ust. Dry Run; reference site

Table 1. (Continued)

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - Nonsignificant departure from ecoregional biocriterion for WWH only (4 IBI or ICI units; 0.5 Iwb units); does not apply to MWH.
[a] - narrative rating used in lieu of ICI (E = exceptional; G = good; MG = marginally good; F = fair; P = poor; VP = very poor)).
[b] - attainment status based on one organism group is parenthetically expressed.

Ecoregion Biocriteria: E. Corn Belt Plain (ECBP)

INDEX - Site Type	WWH	EWH	MWH[c]
IBI - Headwaters	40	50	24
IBI - Wading	40	48	24
Mod. Iwb - Wading	8.3	9.4	6.2
ICI	36	48	22

[c] - Modified Warmwater Habitat for channelized habitats.

poor performance was recorded downstream from the AK 002 outfall. Elk Creek continued to perform at levels consistent with the EWH use designation.

1998 EA Science Dicks Creek Results

In 1998 EA Science performed fish and macroinvertebrate community assessments following standard Ohio EPA protocols. Based on these results, the attainment status in Dicks Creek in 1998 was non-attainment downstream to RM 2.6. At this point use attainment status improved to partial and recovered to full attainment at the mouth (Table 3). Results in the North Branch indicated partial attainment which was limited by the fair performance of the macroinvertebrate community. The non-attainment continued to be driven primarily by the poor performance of the macroinvertebrate community.

1980-95 Ohio EPA Great Miami River Results

Between 1980 and 1995 Ohio EPA assessed the Great Miami River mainstem from upstream of Dayton to the Ohio River which included approximately 90 miles of the lower mainstem. Overall, use attainment status improved from consistent partial and non-attainment between Dayton and Middletown during 1980 and 1989 to predominantly full attainment in 1995. In the immediate reach downstream from the AK Steel 011 outfall, overall biological performance has likewise improved through time. In this case, however, the fish community is the limiting factor in terms of use attainment status as the macroinvertebrates have met the ICI biocriterion since 1989. The fish community showed improvement between 1995 and 1998 at the site immediately downstream from the AK 011 outfall, but did not improve at the next downstream

Table 2. Aquatic life use attainment status for applicable use designations in Dicks Creek, North Branch Dicks Creek, and Elk Creek based on sampling conducted by Ohio EPA during 1995. IBI and MIwb results for individual sampling passes are presented for RM 3.0 to 0.4.

RIVER MILE Fish/Invert.	IBI[a]	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Comment
Dicks Creek (1995)						
			E. Corn Belt Plain - MWH Use Designation (Existing)			
-- /5.2	--	NA	VP*	--	[**NON**]	dst. Moraine Mat., ust. N. Br.
5.0/4.7	43	NA	6*	44.0	**NON**	dst. N. Branch/AK 004
4.4/4.1	41	9.7	P*	58.5	**NON**	dst. Shaker Cr.; ust. AK 015
-- /3.9	--	--	8*	--	[**NON**]	dst. AK 015
3.0/3.7	30/22*	5.8/5.6*	12*	40.0	**NON/NON**	ust. AK 002, dst. AK 003
-- /2.8	--	--	12*	--	[**NON**]	dst. AK 002, ust. landfill trib.
2.6/2.6	34/14*	7.7/4.1*	8*	52.0	**NON/NON**	dst. AK 002 & landfill trib.
			E. Corn Belt Plain - WWH Use Designation (Existing)			
2.4 /1.7	28*/12*	4.4*/2.1*	16*	62.5	**NON/NON**	dst. landfill trib.
0.4/0.2	30*/12*	6.9/1.5*	20*	72.5	**NON/NON**	ust. Mouth
N. Br. Dicks Creek (1995)						
			E. Corn Belt Plain - MWH Use Designation (Existing)			
1.0/1.0	45	NA	8*	42.0	**NON**	ust. AK 004
0.1/0.03	48	NA	VP*	52.5	**NON**	dst. AK 004
Elk Creek (1995)						
			E. Corn Belt Plain - EWH Use Designation (Existing)			
3.7/3.7	46[ns]	9.0[ns]	52	84.0	FULL	ust. Dry Run; reference site

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - Nonsignificant departure from ecoregional biocriterion for WWH only (4 IBI or ICI units; 0.5 Iwb units); does not apply to MWH.
[a] - IBI/MIwb scores before/after spill are reported individually downstream from AK 003 outfall.
[b] - narrative rating used in lieu of ICI (E = exceptional; G = good; MG = marginally good; F = fair; P = poor; VP = very poor)).
[c] - attainment status based on one organism group is parenthetically expressed.

Ecoregion Biocriteria: E. Corn Belt Plain (ECBP)

INDEX - Site Type	WWH	EWH	MWH[d]
IBI - Headwaters	40	50	24
IBI - Wading	40	48	24
Mod. Iwb - Wading	7.9	9.4	6.2
ICI	36	48	22

[d] - Modified Warmwater Habitat for channelized habitats.

Table 3. Aquatic life use attainment status for applicable use designations in Dicks Creek, North Branch Dicks Creek, Shaker Creek, and Millers Creek based on sampling conducted by EA Science during 1998. Ohio EPA calculated scores are used with EA reported scores in brackets when they were different.

RIVER MILE Fish/Invert.	IBI	MIwb	ICI[a]	QHEI	Attainment Status[b]	Comment
Dicks Creek (1998)						
	E. Corn Belt Plain - WWH Use Designation (Existing)					
6.3/6.3	36[ns]	NA	2*	53.5	**NON**	Hendrickson Rd.
	E. Corn Belt Plain - MWH Use Designation (Existing)					
5.0/5.0	52[50]	NA	12*	57.5	**NON**	dst. N. Branch, AK 004
4.4/4.4	26	6.9	12*	48.3	**NON**	dst. Shaker Cr., ust AK 015
3.0/3.0	28	7.3	8*	35.5	**NON**	dst. AK 003, ust. AK 002
	E. Corn Belt Plain - WWH Use Designation (Existing)					
2.6/2.6	44[40]	9.1	22*	55.5	PARTIAL	dst. AK 002; Landfill Trib.
0.4/0.4	42	7.8	32[ns]	77.7	FULL	ust. mouth
N. Br. Dicks Creek (1998)						
	E. Corn Belt Plain - MWH Use Designation (Existing)					
1.0/1.0	50[48]	NA	18*	49.7	PARTIAL	ust. AK 004
Shaker Creek (1998)						
	E. Corn Belt Plain - WWH Use Designation (Existing)					
1.1/1.1	26*	NA	F*	55.0	**NON**	Cincinnati-Dayton Rd.
Millers Creek (1998)						
	E. Corn Belt Plain - WWH Use Designation (Existing)					
0.3/0.3	22*	NA	VP*	37.5	**NON**	Cincinnati-Dayton Rd.

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

ns - Nonsignificant departure from ecoregional biocriterion for WWH only (4 IBI or ICI units; 0.5 Iwb units); does not apply to MWH.

[a] - ICI at RM 6.3 calculated by Ohio EPA; narrative rating used in lieu of ICI (E = exceptional; G = good; MG = marginally good; F = fair; P = poor; VP = very poor)).

[b] - attainment status based on one organism group is parenthetically expressed.

Ecoregion Biocriteria: E. Corn Belt Plain (ECBP)

INDEX - Site Type	WWH	EWH	MWH[c]
IBI - Headwaters	40	50	24
IBI - Wading	40	48	24
Mod. Iwb - Wading	8.3	9.4	6.2
ICI	36	48	22

[c] - Modified Warmwater Habitat for channelized habitats.

Table 4. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in the Great Miami River near Middletown based on sampling conducted by Ohio EPA during 1980, 1989, and 1995.

RIVER MILE Fish/Invert.	IBI	MIwb	ICI	QHEI	Attainment Status[a]	Comment
Great Miami River (1980)						
			E. Corn Belt Plain - WWH Use Designation (Existing)			
53.9/55.0	21*	4.9*	44	--	**NON**	dst. St. Rt. 4; ust. impoundment
-- /51.5	--	--	40	--	[FULL]	dst. Middletown Dam
51.0/50.7	35*	6.9*	32ns	--	PARTIAL	dst. AK 011
50.2/ --	24*	5.7*	--	--	[**NON**]	dst. AK 011; CSO impacts
49.3/49.3	19*	4.6*	36	--	**NON**	ust. SR 73; CSO impacts
Great Miami River (1989)						
			E. Corn Belt Plain - WWH Use Designation (Existing)			
52.0/51.5	26*	6.6*	48	43.0	**NON**	dst. Middletown Dam
50.0/50.9	31*	8.2 ns	48	61.0	PARTIAL	dst. AK 011
49.1/49.3	31*	8.5	48	66.0	PARTIAL	ust. SR 73; CSO impacts
Great Miami River (1995)						
			E. Corn Belt Plain - WWH Use Designation (Existing)			
52.0/51.5	39 ns	9.5	44	78.5	FULL	dst. Middletown Dam
51.4/51.4	*35*	*6.2*	*8*	*51.0*	*NA*	*AK 011 mixing zone*
51.3/51.3	33*	7.5*	38	52.5	PARTIAL	dst. AK 011
51.0/50.9	28*	8.4 ns	38	60.5	PARTIAL	dst. AK 011; ust. Elk Cr.
49.1/49.3	35*	7.8*	40	75.5	PARTIAL	Ust. SR 73; CSO impacts

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - Nonsignificant departure from ecoregional biocriterion for WWH only (4 IBI or ICI units; 0.5 Iwb units); does not apply to MWH.
[a] - attainment status based on one organism group is parenthetically expressed.

Ecoregion Biocriteria: E. Corn Belt Plain (ECBP)

INDEX - Site Type	WWH	EWH	MWH[b]
IBI - Boat	42	48	24
Mod. Iwb - Boat	8.5	9.6	5.8
ICI	36	48	22

[b] - Modified Warmwater Habitat for channelized habitats.

Table 5. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in the Great Miami River near Middletown based on sampling conducted by EA Science during 1998.

RIVER MILE Fish/Invert.	IBI	MIwb	ICI	QHEI	Attainment Status[a]	Comment
Great Miami River (1998)						
E. Corn Belt Plain - WWH Use Designation (Existing)						
52.0/51.5	44	10.1	--	77.3	[FULL]	dst. Middletown Dam
51.3/51.3	38 ns	9.4	--	71.5	[FULL]	dst. AK 011
49.1/49.3	34*	7.1*	--	51.3	[**NON**]	ust. SR 73; CSO impacts

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - Nonsignificant departure from ecoregional biocriterion for WWH only (4 IBI or ICI units; 0.5 Iwb units); does not apply to MWH.
a - attainment status based on one organism group is parenthetically expressed.

Ecoregion Biocriteria: E. Corn Belt Plain (ECBP)

INDEX - Site Type	WWH	EWH	MWH[b]
IBI - Boat	42	48	24
Mod. Iwb - Boat	8.5	9.6	5.8
ICI	36	48	22

b - Modified Warmwater Habitat for channelized habitats.

site at RM 49.1. Other, overlying impacts occur in this segment and likewise contribute to the lack of full recovery that has largely occurred upstream between Dayton and Middletown.

Trend Assessment: 1987 - 1998

The aquatic life use attainment status in Dicks Creek and the North Branch in proximity to the AK discharges has consistently been non-attainment based on the sampling conducted by Ohio EPA (1987, 1995) and EA Science (1998). An exception was full and partial attainment of MWH at two sites immediately downstream from the North Branch in 1987. However, this result changed to non-attainment in both 1995 and 1998. The non-attainment extended downstream and throughout the Warmwater Habitat (WWH) designated segment in 1987 and 1995. This result improved to partial and full attainment in 1998, an indication that the downstream extent of the previous impacts had lessened somewhat. With few exceptions, the attainment status was determined by the

predominantly poor and very poor macroinvertebrate results which failed to attain either the WWH or MWH ICI biocriteria at any location sampled with only three exceptions (Figure 3). While several IBI and MIwb values were well below their respective biocriteria in 1987 and 1995, none were below the biocriteria in 1998. Results in the N. Branch showed partial and full attainment in 1987 and 1998, but non-attainment in 1995, which was due to a failure of the ICI to perform better than poor or very poor.

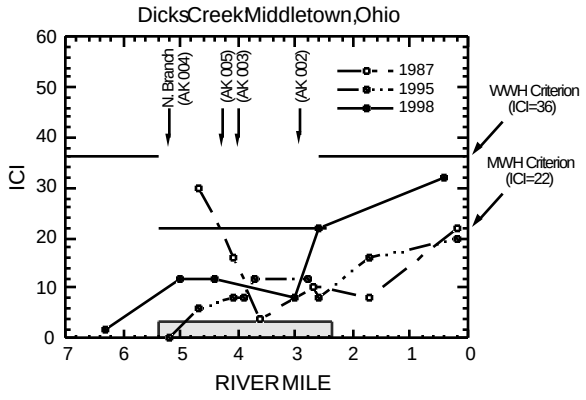

Figure 3. Longitudinal pattern of Invertebrate Community Index (ICI) values at locations sampled in Dicks Creek during 1987 and 1995 by Ohio EPA and 1998 by EA Science. Shaded area is designated MWH.

While the different sensitivities of the fish and macroinvertebrates to pollution impacts in Dicks Creek are likely evidenced in the results, the fish community performance as measured by the IBI may be somewhat "inflated" by the effect of the large flow contributed by AK discharges to a headwater stream. The key phenomenon is that more flow is present than normally occurs in a headwater stream, thus it could be acting as a diversity enhancing factor that is not accounted for in the original calibration of the IBI. It is doubtful that this fully accounts for the difference in response, but it may well be a contributing factor to the comparative lack of degradation reflected by the fish community indices. Flows of this magnitude can also enhance the colonization of the artificial substrates by the macroinvertebrates and potentially skew the results upwards due to similar phenomena. However, the macroinvertebrates were largely in the poor and very poor range suggesting that this factor had little positive influence which suggests that the results would have been even lower without the augmenting effect of the large discharge flows.

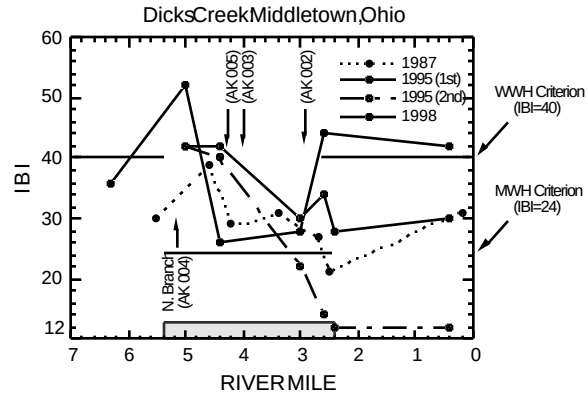

Figure 4. Longitudinal pattern of Modified Index of Well-Being (MIwb) values at locations sampled in Dicks Creek during 1987 and 1995 by Ohio EPA and 1998 by EA Science. Shaded area is designated MWH.

The longitudinal trend in the IBI (Figure 4) shows the extent and magnitude of the improvement noted in the lower 2-3 miles of Dicks Creek between 1987/1995 and 1998. However, it also shows that the magnitude of the impacts in upstream/downstream performance between RM 4.4 and 2.7 have remained similar between years and lower than upstream sites which are located in the habitat modified and MWH designated reach. The MIwb shows a roughly similar and perhaps less pronounced pattern (Figure 5). The ADV statistic and program was used to summarize the overall changes and degree of impairment reflected by each sampling year in the segment of Dicks Creek downstream from the N. Branch confluence and the mouth. This was done to eliminate the potentially confounding influence of varying sampling conducted in upstream reaches and to focus on the conditions in the segment impacted by the AK Steel Middletown facilities. The ADV/mile results for the IBI showed a marked change between 1987/1995 and 1998 (Figure 6) with zero negative ADV/mi. in 1998 and the highest positive ADV/mile value between the three years. Thus based on the IBI results, conditions for the fish community in Dicks Creek have improved through time. The ADV/mile results for the ICI reflect virtually no positive ADV/mile values in any of the three years (Figure 7) which means that all of the results were well below the minimum criterion compatible with the applicable aquatic life use designation. However, the negative ADV/mile value in 1998 was approximately one-

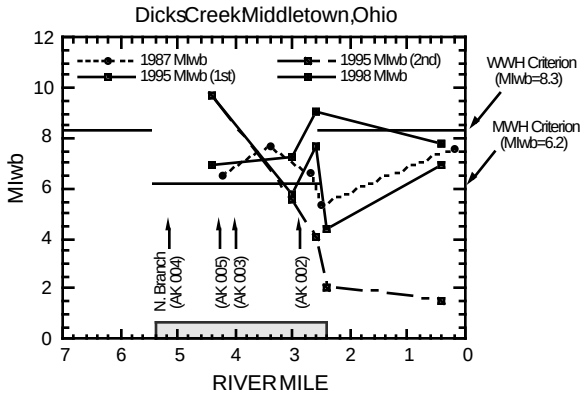

Figure 5. Longitudinal pattern of Invertebrate Community Index (ICI) values at locations sampled in Dicks Creek during 1987 and 1995 by Ohio EPA and 1998 by EA Science. Shaded area is designated MWH.

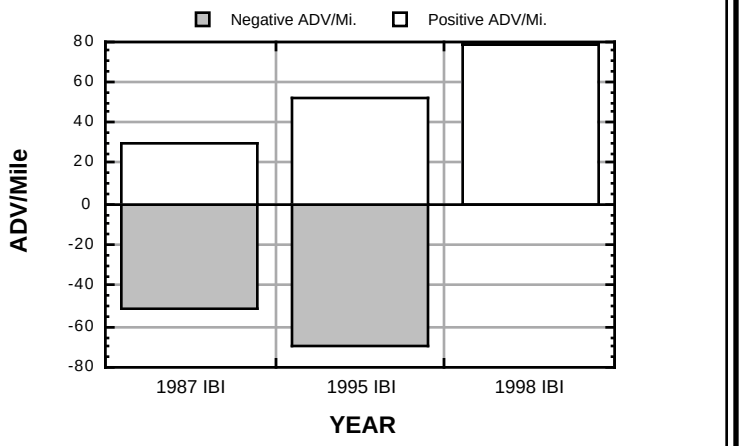

Figure 6. Summary of Area of Degradation Value (ADV) per mile results for the Index of Biotic Integrity (IBI) in Dicks Creek downstream from the N. Branch in 1987, 1995, and 1998.

half of the 1987/1995 results which indicates a proportional lessening in the extent and severity of the impairment (see also Figure 3). This trend is also partially reflected in a reduction in the cumulative miles of poor and very poor quality biological results between 1987/1995 and 1998 (Figure 8). However, the cumulative miles of non-attainment increased slightly between 1987 and 1995. The extent of non-attainment was nearly the same in 1998 as in 1995, except that the miles in poor and very poor condition was reduced by more than 50%. The length of stream in full attainment was less than one mile in any year.

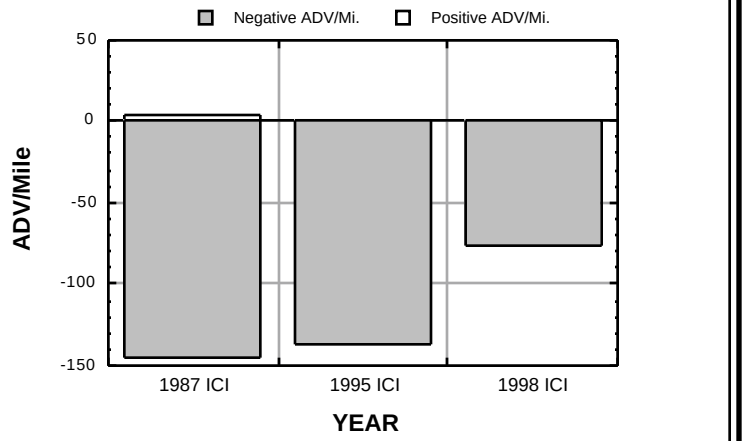

Figure 7. Summary of Area of Degradation Value (ADV) per mile results for the Invertebrate Community Index (ICI) in Dicks Creek downstream from the N. Branch in 1987, 1995, and 1998.

The extreme departure shown by the second fish sampling pass in 1995 underscores the impact that releases of acutely lethal amounts of wastewater have had and can have on Dicks Creek. The fish community results reflected the severe effects of the spill of flushing liquor from outfall 003 and subsequent fish kill that occurred on July 26, 1995. IBI and MIwb scores reflective of very poor conditions were observed downstream from the AK 002 and 003 discharges during the second sampling pass. Similar results were also observed in 1987 when results during the second sampling pass in August were

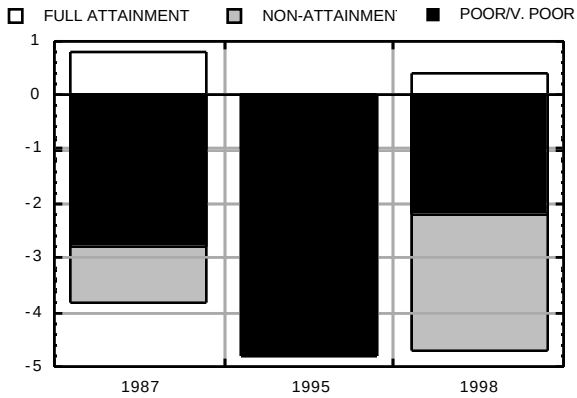

Figure 8. Summary of the cumulative miles of full and non-attainment of the applicable aquatic life uses and poor/very poor biological performance in Dicks Creek downstream from the N. Branch in 1987, 1995, and 1998.

noticeably worse than the first sampling pass in June downstream from the AK landfill tributary (RM 2.65). The field crew conducting the sampling also observed dead aquatic organisms at the mouth of the tributary. An *in situ* test was performed using Dicks Creek water immediately upstream from the landfill tributary and water from the landfill tributary. A single striped shiner and a single longear sunfish were each placed in 5 gallon buckets containing the water from each location. The fish placed in the bucket with landfill tributary water lost equilibrium after 3 minutes of exposure and death occurred after 13 minutes for the striped shiner and 28 minutes for the longear sunfish. No visible adverse effects occurred in the bucket containing the Dicks Creek water after 45 minutes. This information along with the instream sampling results demonstrated the rapid lethality and acute toxicity that has periodically occurred in Dicks Creek. In all, 18 kills of aquatic organisms attributed to the AK Steel Middletown facilities were investigated by Ohio Division of Wildlife between 1965 and 1991.

Synthesis of Results: Associated Causes and Sources of Impairment

The results of biological assessments conducted by Ohio EPA and EA Science between 1987 and 1995 indicate severe departures from the biological criteria for the applicable aquatic life use designations. The results also show that the extent and severity of the impairment has lessened between 1987/1995 and 1998, although the reduction in the miles of stream impairment has been proportionately less. It is also clear that the macroinvertebrate community has exhibited negative response much more so than the fish community. In the case of the macroinvertebrates, impairment is reflected both upstream and downstream from AK facilities and discharges. This is due to the influence of multiple sources which include individual discharges and land use impacts. This increases the challenges involved in determining which sources are predominantly associated with the observed impairments. In such cases, differential responses exhibited by the aquatic communities within the same relative degree of impairment can provide important insights about the role of multiple stressors as can an examination of the accumulation of different stress, exposure, and response indicators along the receiving stream. As such two different sets of analysis were used in an attempt to distinguish the different types of impact that occur along the length of Dicks Creek.

Biological Response Signature Analysis

Multiple stressors affect Dicks Creek and include point source discharges of different sizes and types of processes, nonpoint source runoff from urban and agricultural areas, and instream habitat modifications as a result of flood control practices by the Miami Conservancy District (MCD). The latter practice coupled with a failure of the aquatic communities to meet the WWH biocriteria resulted in a redesignation to the MWH use for that portion of Dicks Creek that is maintained by the MCD. Yoder and Rankin

(1995) developed the concept of biological response signatures which are characteristic responses within fish and macroinvertebrate assemblages which consistently indicate a particular type or category of stressor. In Dicks Creek the predominant stressors are toxic and conventional pollution from the AK Middletown facility and the habitat modification performed for flood control purposes. The question becomes which source is most associated with the biological results obtained in Dicks Creek between 1987 and 1998.

Macroinvertebrate Response Signatures

As described in Yoder and Rankin (1995), the macroinvertebrate "signature" of a complex toxic impact is characterized by three aspects of the data: the ICI score, the number of qualitative EPT taxa, and proportion of individuals comprised of the midge genus *Cricotopus.* The response of these three components to a complex toxic impact are as follows (based on the assessment of the Ohio EPA statewide macroinvertebrate database performed by Yoder and Rankin 1995):

ICI <14-18
Qualitative EPT <2-4
%*Cricotopus* >5.0

The concurrence of all three was strongly indicative of a complex toxic impact as opposed to other potential impact types (e.g., conventional municipal/industrial, CSOs/urban, channelization, agricultural NPS, flow alteration, CSOs/urban with toxics, and livestock access). This particular impact type was characterized by Yoder and Rankin (1995) as an impact from the complex combination and interaction of major WWTP and industrial point sources that comprise a significant fraction of the summer base flow of the receiving stream and where one or more of the following have occurred: serious instream chemical water quality impairment involving toxics, recurrent whole effluent toxicity, fish kills, or severe sediment contamination involving toxics.

A compilation of the macroinvertebrate data collected from Dicks Creek by Ohio EPA in 1995 and EA Science in 1998 appears in Table 6. This includes summarized information about the key variables of the biological response signatures concept developed by Yoder and Rankin (1995). This included the ICI score, qualitative EPT taxa, *%Cricotopus* midges, %toxic tolerant individuals, and %organic/nutrient/D.O. tolerant individuals and a narrative description of the response exhibited by the macroinvertebrate community was at each site. Yoder and Rankin (1995) found that a combination of ICI scores $\leq$ 18, EPT $\leq$ 4, and *%Cricotopus* > 5% consistently indicated toxic conditions. In their analysis, Yoder and Rankin (1995) also grouped macroinvertebrate taxa by a broader toxics tolerant

group (%toxic tolerant individuals) and an organic/nutrient enrichment/D.O. tolerant group (%organic/nutrient/D.O. tolerant individuals). The following groupings were used (after Yoder and Rankin 1995).

Toxics Tolerant	Organic/Nutrient/D.O. Tolerant
Cricotopus spp	Oligochaeta
Dicrotendipes simpsoni	*Glyptotendipes (G.)* sp (not *G.(G.) barbipes*)
Glyptotendipes (G.) barbipes	*Chironomus (C.) decorus* group
Polypedilum (P.) fallax group	*Chironomus (C.) riparius* group
Polypedilum (P.) illinoense	*Dicrotendipes lucifer*
Nanocladius (N.) distinctus	*Dicrotendipes neomodestus*
	Polypedilum (Tripodura) scalaenum group
	Turbellaria
	Physella sp
	Simulium sp

In order to distinguish the predominant character of the impairments to the macroinvertebrate community in Dicks Creek, the aggregations of these specific taxa groupings were compared (Table 6). The response at a site was characterized as toxic if two or three of the principal Yoder and Rankin (1995) guidelines were met and/or if the %toxic tolerant individuals was greater than 35%. An organic/nutirent/D.O. enrichment signature was indicated if the %organic/nutrient/D.O. individuals were greater than 35%. Both signatures were assigned if a mix of the above benchmarks were met. In this analysis, it was important to determine if the response signature was characteristic of a complex toxic impact or some other response since the community indices and accompanying evaluation of attainment status and general condition indicated pervasive degradation throughout the study area.

The Ohio EPA results from 1995 showed a marked change in the character of the response of the macroinvertebrate community along the length of Dicks Creek. The extreme upstream site was essentially desiccated and contained only shallow pools comprised of backwater from the N. Branch. So few organisms were collected that the response signature was not possible to determine. At RM 4.7 downstream from the N. Branch confluence and the AK 004 outfall, the response was a mix of complex toxic and enrichment. While the ICI/EPT/*%Cricotopus* essentially met the guidelines established by Yoder and Rankin (1995) for the complex toxic impact type, the sample was also predominated by organisms characteristic of enriched conditions. Downstream from this point, the response signature was consistently and predominantly toxic until the mouth where the response was mixed. In the N. Branch the response upstream from AK 004

Table 6. Assignment of predominant response by the macroinvertebrate community based on sampling conducted by Ohio EPA in 1995 and EA Science in 1998 using the biological response signatures as described by Yoder and Rankin (1995).

Location RM (Source)	ICI	Qual. EPT	Percent Cricotopus	%Toxic Tolerant	%Organic/ Nutrient/D.O.	Response Signature[1]
			Ohio EPA 1995			
Dicks Creek						
5.2 (Mor. Mat.)	**VP**[3]	**1**	-	-	-	Indeterminant[2]
4.7 (AK 004)	**6**	**4**	4.9	9.1	*79.5*	Toxic/Enriched
3.9 (AK 015)	**8**	**1**	**32.0**	**63.2**	21.9	Toxic
3.7 (AK 003)	**12**	**0**	**16.2**	**70.3**	11.4	Toxic
2.8 (AK 002)	**12**	**4**	**15.8**	**72.3**	15.7	Toxic
2.6 (AK landfill trib.)	**8**	**3**	**21.9**	**85.0**	7.1	Toxic
1.7 (Amanda Elem.)	**16**	7	**26.8**	**59.8**	11.7	Toxic
0.2 (Mouth)	20	5	**10.6**	14.1	*53.8*	Enriched/Toxic
North Branch						
1.0 (Urban)	**8**	1	7.1	7.4	81.5	Enriched
0.03 (AK 004)	**VP**	0	Predominant	Present	None	Toxic
			EA Science 1998			
Dicks Creek						
6.3 (NA)	**2**	**3**	0.0	0.0	*90.4*	Enriched
5.0 (AK 004)	**12**	6	**51.7**	**51.7**	24.7	Toxic
4.4 (AK 004)	**12**	**4**	**51.4**	**52.8**	12.7	Toxic
3.0 (AK 003)	**8**	**3**	8.1	9.0	*63.8*	Toxic/Enriched
2.6 (AK 002 & landf.)	22	5	**36.7**	**37.4**	22.2	Toxic
0.4 (Mouth)	32	8	1.1	2.2	2.4	None (biocriteria met)
North Branch						
1.0 (Urban)	**18**	**3**	1.0	1.3	*69.8*	Enriched
Millers Cr.						
0.3 (Industrial)	**0**	**1**	0.0	0.0	*35.0*	Enriched
Shaker Cr.						
0.1 (Domestic/Ind.)	**4**	5	0.0	**38.5**	*47.4*	Enriched

[1] Predominant response signature listed first when two signatures were evident.
[2] Insufficient number of organisms collected due to a lack of water; no predominance by any group.
[3] Values in boldface type are within toxic response criteria for that metric or attribute.

was enrichment and toxic downstream. Thus in 1995 the response downstream from AK 004 was predominantly toxic.

The EA Science results from 1998 showed similar results to Ohio EPA in 1995, except that the strength of the toxic signature at the sites directly impacted by AK Steel discharges was somewhat reduced with a stronger enrichment signature at RM 3.0 and no signature at RM 0.4 where the biocriteria were met. While still indicating a predominantly toxic impact, there was a lessening of the severity of that impact with a slight lessening of the longitudinal extent of the impairment. All other sites outside of the direct influence of the AK Steel discharges exhibited an enrichment signature (Table 6).

A similar compilation of the fish assemblage data collected from Dicks Creek by Ohio EPA in 1995 and EA Science in 1998 was accomplished (Table 7). This includes summarized information about the key variables of the response signatures previously identified by Yoder and Rankin (1995; IBI amd MIwb scores, %DELT anomalies, %tolerant individuals, number of sensitive species, density, and number of darter species) and the number of these variables that exhibited a toxic signature at each site. Thresholds for toxic signatures were obtained from Yoder and Rankin (1995) and included IBI $\leq$ 22, MIwb $\leq$ 5.9, %DELT $\geq$ 10%, %tolerant > 70%, sensitive species <1, density < 150, and dater species < 1. The number of toxic signatures expressed at each site are indicated in Table 7 with a higher number of accumulated signatures indicating an increasingly strong indication that toxicity contributed to the response and observed impairments of the applicable designated use.

Evidence of toxic responses by the fish community were periodic and indicated the influence of acute, episodic impacts, particularly in the results from 1987 and 1995 (Table 7). The most consistent responses occurred at RM 2.5 in 1987 and RM 2.6 in 1995, both of which are downstream from the AK landfill tributary. In 1995, the toxic impact signature appeared strongly during the second sampling pass which followed the large spill of flushing liquor from outfall 003 and the subsequent fish kill, all of which occurred after the first sampling pass. The comparatively low incidence of a sustained, chronic complex toxic signature described by Yoder and Rankin (1995) should not be construed as an absence of toxic impacts to the fish community or the presence of toxicity in general. In this case the response by the fish community, while not consistently characteristic of a chronically toxic influence, does include a repeated risk of episodic and severe acute toxic impacts. It may well be that in the case of Dicks Creek the proportionately large effluent flow is an offsetting factor which may contribute to the lack of a sustained, chronic toxic response by the fish community as has been seen in other Ohio streams and rivers that are impacted by legacy pollutants and complex industrial sources. In contrast, the response exhibited by the macroinvertebrates is consistent with the chronic toxic response described by Yoder and Rankin (1995) and is a strong argument for the inclusion of multiple organism groups in

Table 7. Expression of toxic response signatures among selected metrics and aggregations of fish assemblage data in Dicks Creek based on sampling conducted by Ohio EPA in 1987 and 1995 and EA Science in 1998 using the biological response signatures as described by Yoder and Rankin (1995).

Location **RM** (Source)	IBI	Modified Iwb	%DELT Anomalies	Percent Tolerant	Sensitive Species	Density[1] (No./300m)	Darter Sp.	#Toxic Signatures[2]
				Ohio EPA 1987[3]				
Dicks Creek								
5.5 (Background)	38	NA	0.1	6.0	**0**	2288	**0**	2/6
5.5 (Background)	24	NA	0.1	**70**	**0**	820	1	2/6
4.6 (AK 004)	40	NA	0.0	30	2	509	**0**	1/6
4.6 (AK 004)	38	NA	1.3	23	2	220	**0**	1/6
4.6 (AK 004)	38	NA	1.4	20	2	854	1	0
4.2 (Shaker Cr.)	26	6.6	3.4	62	3	222	**0**	1/7
4.2 (Shaker Cr.)	34	7.0	1.8	42	2	312	1	0
4.2 (Shaker Cr.)	26	**5.9**	1.3	58	3	**143**	1	2/7
3.4 (AK 003)	30	7.3	0.8	31	1	613	**0**	1/7
3.4 (AK 003)	32	8.4	0.3	31	2	1347	**0**	1/7
3.4 (AK 003)	30	7.3	0.5	30	1	444	**0**	1/7
2.7 (AK 002)	28	**5.8**	3.8	52	1	232	**0**	2/7
2.7 (AK 002)	24	7.3	2.4	51	2	368	**0**	1/7
2.7 (AK 002)	28	6.9	**11.0**	36	2	228	**0**	2/7
2.5 (AK landfill)	24	6.4	**12.3**	51	2	186	**0**	2/7
2.5 (AK landfill)	**22**	6.2	4.0	**78**	1	**93**	**0**	4/7
2.5 (AK landfill)	**18**	**3.2**	**13.3**	42	**0**	**50**	**0**	6/7
0.2 (Mouth)	28	7.6	2.6	34	4	414	**0**	1/7
0.2 (Mouth)	34	7.9	7.7	36	3	366	2	0
0.2 (Mouth)	32	7.5	5.6	36	4	351	1	0
North Branch								
1.1 (Urban)	34	NA	0.0	**74**	**0**	**147**	2	3/6
1.1 (Urban)	36	NA	0.0	53	**0**	374	2	1/6
0.1 (AK 004)	40	NA	0.1	31	2	2186	1	0
0.1 (AK 004)	44	NA	0.1	20	2	3150	2	0
0.1 (AK 004)	44	NA	0.7	25	4	1474	2	0

[1] Metric 12 of Ohio EPA modified IBI - numbers/300m less highly tolerant species.
[2] Number of metrics or attributes which reflect a toxic response after Yoder and Rankin (1995).
[3] Values in boldface type are within toxic response criteria for that metric or attribute.

Table 7. (continued)

Location **RM** (Source)	IBI	Modified Iwb	%DELT Anomalies	Percent Tolerant	Sensitive Species	Density[1] (No./300m)	Darter Sp.	#Toxic Signatures[2]
				Ohio EPA 1995[3]				
Dicks Creek								
5.0 (AK 004)	42	NA	0.9	17	4	376	2	0
5.0 (AK 004)	42	NA	1.3	17	7	222	2	0
4.4 (Shaker Cr.)	42	9.7	1.4	18	8	878	2	0
4.4 (Shaker Cr.)	40	9.7	1.0	20	6	1092	2	0
3.0 (AK 003)	30	**5.8**	9.4	51	5	**83**	**0**	4/7
3.0 (AK 003)	**20**	**5.6**	1.4	18	2	**104**	**0**	4/7
2.6 (002 & landf.)	34	7.7	3.0	46	6	**130**	**0**	2/7
2.6 (002 & landf.)	**14**	**4.1**	0.0	33	**0**	**16**	**0**	5/7
2.4 (AK landfill)	28	**4.4**	**11.0**	**72**	5	**40**	1	4/7
2.4 (AK landfill)	**12**	**2.1**	0.0	**86**	**0**	**2**	**0**	6/7
0.4 (Mouth)	30	6.9	1.7	59	9	**118**	4	1/7
0.4 (Mouth)	**12**	**1.5**	**25.0**	25	**0**	**5**	**0**	6/7
North Branch								
1.0 (Urban)	42	NA	0.4	35	2	1108	2	0
1.0 (Urban)	48	NA	0.1	16	2	3124	4	0
0.1 (AK 004)	50	NA	0.8	23	6	632	2	0
0.1 (AK 004)	46	NA	0.4	7.0	4	1086	3	0
				EA Science 1998[3]				
Dicks Creek								
6.3 (Upstream)	36	NA	0.0	54	**0**	1220	2	1/6
5.0 (AK 004)	52	NA	0.0	21	5	1398	5	0
4.4 (Shaker Cr.)	26	--	0.0	51	5	174	2	0
3.0 (AK 003)	28	--	0.0	40	3	221	1	0
2.6 (002 & landf.)	44	--	0.0	42	8	342	4	0
0.4 (Mouth)	42	--	0.0	26	8	297	4	0
North Branch								
1.0 (Urban)	50	NA	0.0	30	3	2751	3	0

[1] Metric 12 of Ohio EPA modified IBI - numbers/300m less highly tolerant species.
[2] Number of metrics or attributes which reflect a toxic response after Yoder and Rankin (1995).
[3] Values in boldface type are within toxic response criteria for that metric or attribute.

bioassessments. In Dicks Creek and the N. Branch, the macroinvertebrates were clearly the limiting factor in the continued non-attainment of aquatic life uses; a predominant cause associated with this non-attainment remains toxicity from the AK Steel discharges.

Multiple Indicators Matrix

Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures in determining the associated causes and sources of environmental condition. This integrated approach is outlined in Figure 1 and includes a hierarchical continuum from administrative to true environmental indicators which is paralleled by the roles of indicators from stressor to response. The identification of impairment is based on response indicators and is straightforward - the numerical biological criteria are the principal arbiter of aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria in the role of principal arbiter within a weight of evidence framework has been extensively discussed elsewhere (Karr *et al*. 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995).

Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represents the association of impairments (based on response indicators) with available stressor and exposure indicators with linkages to the biosurvey data being based on previous experience within the strata of analogous situations and impacts. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified. This is the basis of the biological response signatures concept developed by Yoder and Rankin (1995).

For Dicks Creek the largest body of information from all of the relevant indicator levels (Figure 1) is that collected in 1995 and used to complete the middle and lower Great Miami River assessment (Ohio EPA 1997). This and other available information was used to construct a detailed matrix of environmental indicators information (Figure 9). This matrix includes the aquatic life use attainment status, five stressor indicators, six exposure indicators, and four response indicators arranged in an upstream to downstream direction for Dicks Creek and the mainstem Great Miami River. Each representative indicator column is shaded with darker shading indicating increasingly serious departures from that compatible with the existing use designation or a desired state consistent with attainment of the use. The data used to develop this table was compiled from the 1995 assessment and the underlying documentation for the summary data that appeared in that report. For some of the indicator information such as NPDES permit exceedences, spills, fish kills, WET test results, and the instream chemical results, information is available only for selected locations and this was placed at the nearest or best

Figure 9. Environmental indicators matrix for Dicks Creek and the Great Miami River mainstem near the AK 011 outfall based on data and information compiled by Ohio EPA in 1995 and reported in Ohio EPA (1997). Darker shading indicates the severity of departure from criteria or the severity of the impact implicated by the results.

	DES-IGNATED USE	STRESSOR INDICATORS					EXPOSURE INDICATORS						RESPONSE INDICATORS			
SEGMENT	Attain-ment Status[a]	Permit Exceed ences	Spills/ Re-leas	Fish Kills	Toxici-ty (WET)	Habitat Modifica-tions	Water Column Chem.[b]	Water Column PAHs	Sediment Metals	Sedi-ment PAHs	Sedi-ment PCBs	Habitat (QHEI)	IBI[c]	MIwb	ICI[d]	BRS[e]
Dicks Creek & N. Branch - MWH Use Designation																
Dst. Moraine Materials (RM 5.2)	[NON]	--	0	--	--	--	15/8 [0>max.]	--	**HIGHLY** (As,Cr)	0 PAH det.	0 PCB det.	--	--	NA	**VP***	
N. Branch Ust. AK 004 (RM 1.0)	**NON**	--	0	--	--	Main-tained Channel	5/4 [0>max.]	0 PAH	ELEVAT-ED (Al,Ba,Cr)	6 PAH det. [5>LEL]	0 PCB det.	42.0	45	NA	**8***	EN-RICH-MENT
N. Branch Dst. AK 004 (RM 0.1)	**NON**	26	1	0	YES	Recov-ering Channel	13/7 [0>max.]	0 PAH	Non/ Slight	0 PAH det.	0 PCB det.	52.5	48	NA	**VP***	TOXIC
Dst. N. Branch & AK 004 (RM 5.0/4.7)	**NON**	--	--	--	--	Main-tained Channel	12/6 [0>max.]	0 PAH	ELEVAT-ED (As,Cr)	0 PAH det.	0 PCB det.	44.0	43	NA	**6***	EN-RICH-MENT/ TOXIC
Dst. Shakers Cr. (RM 4.4/4.1)	**NON**	--	--	--	--	Recov-ering Channel	--	--	--	--	--	58.5	41	9.7	**P***	TOXIC
Dst. AK 015 (RM 3.9)	[NON]	1	1	Jun 29, 1995 (10K+)	NO	--	--	--	--	--	--	--	--	--	**8***	TOXIC
Dst. AK 003 (RM 3.0/3.7)	**NON**	8	5	Jul 26, 1995 (12K+)	YES/ NO	Main-tained Channel	23/16 **[10>**	17 PAH (36% det.)	**EXTREME** (Cr)	4 PAH det. [3>LEL]	0 PCB det.	40.0	30/**22***	5.8/**5.6***	**12***	TOXIC
Dst. AK 002 (RM 2.8)	[NON]	5	2	0	NO	--	--	--	--	--	--	--	--	--	**12***	TOXIC
Dst. Landfill Trib. (RM 2.6)	**NON**	0	0	0	--	Main-tained Channel	12/10 **1>max.**	8 PAH (42% det.)	**HIGHLY** (Cr)	9 PAH det. [8>LEL]	**EX-TREME**	52.0	34/**14***	7.7/**4.1***	**8***	TOXIC

Figure 9 (continued).

SEGMENT	DESIGNATED USE	STRESSOR INDICATORS					EXPOSURE INDICATORS						RESPONSE INDICATORS			
	Attainment Status[a]	Permit Exceedences	Spills/ Releases	Fish Kills	Toxicity (WET)	Habitat Modifications	Water Column Chem.[b]	Water Column PAHs	Sediment Metals	Sediment PAHs	Sediment PCBs	Habitat (QHEI)	IBI[c]	MIwb	ICI[d]	BRS[e]
Dicks Creek - WWH Use Designation																
Amanda Elem. (RM 2.4/1.7)	**NON**	--	0	0	--	Recovering Channel	--	--	--	--	--	62.5	28*/**12***	**4.4***/ **2.1***	16*	TOXIC
Ust. Mouth (RM 0.4/0.2)	**NON**	--	--	--	--	Natural Channel	8/7 [0>max.]	1 PAH (1 of 3 det.)	**HIGHLY** (Cd)	9 PAH det. [8>LEL]	**EXTREME**	72.5	30*/**12***	6.9*/ **1.5***	20*	EN-RICHMENT
Great Miami River - WWH Use Designation																
Dst. Middletown Dam (RM 52.0/51.5)	FULL	--		0	--	Natural Channel	3/3 [0>max.]	0 PAH	Non/ Slight	1 PAH det. [<LEL]	0 det.	78.5	39[ns]	9.5	44	EN-RICHMENT
AK 011 Mixing Zone (RM 51.4)	NA (Mix. zone)	30	5	0	YES	NA	--	--	--	--	--	NA	***35***	***6.2***	***8***	TOXIC
Dst. AK 011 (RM 51.3)	PART.	--	--	0	--	Recovering Channel	7/4 [0>max.]	0 PAH	EXTREME (As,Cd,Cr, Cu,Fe) **HIGHLY** (Ba,Pb)	17 PAH det. [9>LEL: **2>SEL**]	0 det.	52.5	33*	7.5*	38	EN-RICHMENT
Ust. Elk Cr. (RM 51.0/50.9)	PART.	--	--	0	--	Recovered Channel	--	--	--	--	--	60.5	28*	8.4[ns]	38	EN-RICHMENT

FOOTNOTES:

[a] Attainment status based on one organism group is parenthetically expressed.

[b] includes conventional, nutrients, demand, and heavy metals paarameters; results given as number of exceedences/parameters of chronic aquatic concentration (CAC; 30 day averge criterion), criterion maximum concentration (CMC; outside mixing zone maximum), and final acute value (FAV) and number of parameters with exceedences; exceedences of CMC and FAV are further highlighted.

[c] IBI and Miwb results given for individual sampling pass in area affected by the July 26, 1995 fish kill.

[d] Narrative evaluation used in lieu of ICI in flow limited situations or in the absence of an ICI value (E=Exceptional; G=good; MG=Marginally Good; F=Fair; P=Poor; VP=Very Poor).

[e] Biological Response Signature (BRS) based on macroinvertebrate commuity composition and response.

* Significant departure from ecoregional biocriteria; poor and very poor results are in boldface type and underlined.

ns Nonsignificant departure from ecoregional biocriteria for WWH only (4 IBI or ICI units; 0.5 MIwb units); does not apply to MWH use.

representative biological sampling location in Figure 9.

The accumulation of indicators that show increasingly serious departures from their respective criteria or other benchmarks in Dicks Creek were most numerous at the location downstream from the AK 003 outfall. The only indicator that did not show at least a detection was sediment PCBs. In the matrix this indicator did not become visible until downstream from the AK landfill tributary in which much of the PCB contamination exists. Exceedences of selected indicators were evident at most of the other sampling locations including those outside of the direct influence of AK Steel outfalls. In particular, RM 5.2 in Dicks Creek had several water quality criteria exceedences and highly elevated metals in sediment and RM 1.0 in the N. Branch (represented here by chemical sampling at RM 0.75) had water quality criteria exceedences, elevated metals, and detected concentrations of PAHs in sediments. These two sites are presumably upstream from the direct influence of AK Steel wastewater outfalls, thus impacts do occur from other sources in the study area. However, while these correspond to failures to meet the biocriteria for at least the ICI, and hence non-attainment of the aquatic life use, the biological response signatures are not representative of toxic impacts that would be expected from AK Steel discharges. The accumulation of toxic stressor and exposure indicators associated with a toxic biological response signature are downstream from AK Steel outfalls and are the most severe where there is an accumulation of stressor and exposure indicators that are connected to AK Steel discharges. The co-occurrence of toxic chemical compounds and substances that are byproducts of the steel making process and which are characteristic of the complex toxic impact type described by Yoder and Rankin (1995) and the commensurate toxic response by the macroinvertebrates implicates the role of selected AK outfalls in the failure to attain the applicable aquatic life use. Other than the evidence in the habitat modification indicator and QHEI scores, there is little reason to believe that habitat alone played a major role in the observed results, other than that already incorporated into the biological criteria for the MWH use designation.

In the Great Miami R. Mainstem, the accumulation of WQS criteria exceedences and other indications of adverse impact occurred immediately downstream from the AK 011 outfall, but the severity of the biological impact is much less and the response signature was toxic only within the mixing zone.

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