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Assessment of the Biological Assemblage Condition of Small Headwater Streams in Ohio Subject to the Proposed General Use Provisions of Ohio's Water Quality Standards

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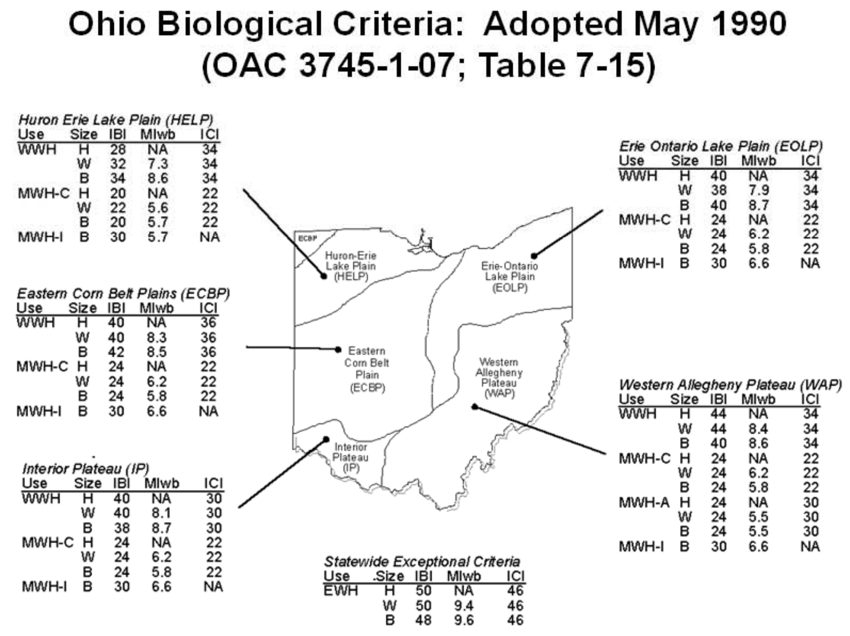

Ohio Biological Criteria: Adopted May 1990
(OAC 3745-1-07; Table 7-15)

Huron Erie Lake Plain (HELP)

Use	Size	IBI	MIwb	ICI
WWH	H	28	NA	34
	W	32	7.3	34
	B	34	8.6	34
MWH-C	H	20	NA	22
	W	22	5.6	22
	B	20	5.7	22
MWH-I	B	30	5.7	NA

Eastern Corn Belt Plains (ECBP)

Use	Size	IBI	MIwb	ICI
WWH	H	40	NA	36
	W	40	8.3	36
	B	42	8.5	36
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA

Interior Plateau (IP)

Use	Size	IBI	MIwb	ICI
WWH	H	40	NA	30
	W	40	8.1	30
	B	38	8.7	30
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA

Erie Ontario Lake Plain (EOLP)

Use	Size	IBI	MIwb	ICI
WWH	H	40	NA	34
	W	38	7.9	34
	B	40	8.7	34
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA

Western Allegheny Plateau (WAP)

Use	Size	IBI	MIwb	ICI
WWH	H	44	NA	34
	W	44	8.4	34
	B	40	8.6	34
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-A	H	24	NA	30
	W	24	5.5	30
	B	24	5.5	30
MWH-I	B	30	6.6	NA

Statewide Exceptional Criteria

Use	.Size	IBI	MIwb	ICI
EWH	H	50	NA	46
	W	50	9.4	46
	B	48	9.6	46

Peter A. Precario, Executive Director
Dr. David J. Horn, Board President

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MBI Technical Report MBI/2011-6-6

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Foreword

The analyses contained in this report were originally developed by the Midwest Biodiversity Institute at the request of U.S. EPA, Region V under contract EP-C-09-001 and Work Assignment 2-01. The original version of the report and its contents were intended for use by U.S. EPA, Region V and at their sole discretion. Since that time other issues with small headwater streams have emerged specifically the importance of assessing headwater streams that are typically in the range of 1-20 square miles. Because the June 2011 version of this report focused on similar stream sizes the analyses and conclusions are equally relevant to that subject. This revised version of the June 2011 report includes revisions intended to better amplify these issues, but the technical analyses are unchanged.

The analyses herein are technical and were originally intended to inform the process of evaluating changes that were proposed to the Ohio WQS in 2011. This report concludes that the current practice of conducting use attainability analyses (UAA) that have been accomplished for more than 30 years is adequate for the management of drainage issues under the CWA. It was not the intent of this report to examine all of the policy issues surrounding the application or proposed removal of the biocriteria from the proposed Drainage Uses, but the technical analyses herein should be informative about the inherent risks of deleting the biocriteria and other likely consequences of the proposed Drainage Uses (**DUs**). The analyses are also informative for determining the potential impact and propagation of assessment errors by limiting watershed monitoring to sites of >10-20 square miles as opposed to the routine inclusion of monitoring sites <10 square miles.

Executive Summary

For the past 20+ years the Ohio Tiered Aquatic Life Use (TALU) framework of designated uses and biocriteria has fostered an effective and balanced approach to protecting, restoring, and enhancing the quality of Ohio streams and rivers. This framework provides appropriate and effective levels of protection for Ohio streams and rivers and sets reasonably attainable restoration goals for the majority of Ohio streams and rivers that meet the Clean Water Act “protection and propagation of fish, shellfish, and wildlife” goal (CWA Section 101[a][2]). This framework at least implicitly recognizes that the CWA goal may not be feasibly attainable in the short-term in certain streams and it provides a reasonable and scientifically sound methodology for identifying waters where CWA goals are not immediately attainable via a structured Use Attainability Analysis (UAA) process. The UAA process considers several of the same factors that are included as default triggers in the **DU** proposal, but carefully weighs each one on an individual stream and stream segment basis as opposed to a default basis. This practice is essential because of the imperfect ability of physical factors alone to accurately predict aquatic assemblage condition or potential and as such it meets the intent of the existing use and attainable use clauses of the U.S. EPA water quality regulations. This process is tractable as evidenced by the hundreds of aquatic life use reviews and revisions that have been codified in the Ohio WQS as a routine outcome of the Ohio EPA monitoring and assessment program. The maintenance of the monitoring program at its former levels of spatial resolution seen in the late 1990s is essential to the integrity and validity of the UAA process.

The 2011 joint Ohio EPA/Ohio DNR proposal to develop Drainage Use (**DU**) categories (Upland Drainage, <3.125 sq. mi.; and Water Conveyance, >3.125 sq. mi.; herein referred to as Drainage Uses, **DUs**), based on streams identified as being "historically channelized" (**HC**) prompted U.S. EPA to commission an analysis of the scientific underpinnings of four key assumptions that underlie the joint proposal.

1. ***The Upland Drainage use, in particular, implies that streams less than 3.125 sq. mi. that have evidence of being "Historically Channelized" are unlikely to have habitat features compatible with WWH or better aquatic life uses.***

   The analysis of Ohio EPA data from streams likely to be considered Historically Channelized (**HC**) is that, statewide, one-third to one-half of such streams are capable of attaining the Warmwater Habitat (WWH) aquatic life use ***or better***. Even when such estimates were restricted to "low gradient" streams (<3% slope; <15.85 ft./ mi.), one-third to one-half of such waters either attain or have the realistic potential to attain the WWH aquatic life use or better. Even the use of a relevant geographic construct such as level IV subregions would still result in use designation assignment errors if applied as a "default" outside of the current UAA process. Such errors will be precluded only by continuing to rely on the existing system of designated aquatic life uses as applied within the current UAA framework. There is no technical justification to support the default application of the proposed **DUs** as is envisioned by the joint Ohio EPA-Ohio DNR proposal and the attendant Ohio DNR drainage manual.

2. ***The current biocriteria would not apply to the DUs under the assumption that downstream water quality and aquatic life uses will be protected through implementation of TMDLs for pollutants, particularly for nutrients.***

   A major objective of this review is to determine whether the baseline management option for **DUs** (e.g., trapezoidal channels) is consistent with the stated requirement of protecting for downstream uses. Recent scientific literature has identified the integral role of headwater streams and their habitat quality in sequestering and assimilating nutrients in runoff. In Ohio, strong associations between headwater stream habitat quality and concentrations of nutrients such as phosphorus, organic nitrogen, and nitrates has been demonstrated. While upland sources of nutrients can readily overwhelm the capacity of a headwater stream to assimilate nutrients, upland treatment alone via BMPs appears insufficient to protect downstream uses. The effective processing of nutrients is greater in streams with higher quality habitat and contemporary research indicates that the capacity for removing nutrients is greatest in very small headwater streams where the substrate surface to flow volume ratio is the highest; these are the target streams for the **DUs**. Trapezoid channels[1] in Ohio are strongly correlated with poor (fine and embedded) quality substrates which inhibits nutrient assimilation and reduces the substrate to flow ratios. Given typical application rates of nutrients on row crops and that an expansion of trapezoidal channels would likely occur with

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[1] The default option for improving drainage per the options for DUs under the proposed implementation procedures (draft Ohio DNR Drainage Manual 2008).

the proposed **DUs**, the assertion that downstream uses will be protected is suspect. Based on the available data it is likely that nutrient conditions would worsen in downstream waters rather than improving if more headwater streams were converted to or maintained as trapezoidal channels.

3. ***The removal of biocriteria from DUs would result in a dramatic change in how Ohio identifies impaired waters.***

   Under the **DU** proposal, biocriteria would not apply at <3.125 sq. mi. and chemical criteria alone would apply under a General Uses framework. Under the **DU** proposal it seems likely that any monitoring would be chemical only. Prior analyses of Ohio data have shown that a primary reliance on chemical monitoring alone not only significantly underestimates aquatic life impairments, but it can also mischaracterize the causes of impairments. The Ohio biocriteria are calibrated for streams ≈1.0 mi.^2 and larger and they have been effectively applied in small streams where the **DUs** are being proposed as a replacement for the WWH suite of uses. A concern with the application of the proposed **DUs** is the lack of a sound scientific basis for the **DU** associated stream management practices and doubts and uncertainties about their impacts on stream ecosystem processes. Rather than simply assuming that practices such as trapezoidal channels and two-stage ditch designs will maintain important ecosystem services such as nutrient sequestration and assimilation, there is a need to further quantify the effects of **DUs** on these vital ecosystem services. Such an assessment could be used to highlight more beneficial stream management practices (e.g., natural stream channel designs). Such practices would maximize multiple ecosystem services and work most effectively within the existing TALU framework that embraces multiple ecosystem services rather than simply eliminating them.

4. ***The current biocriteria were never intended for application to streams where the DUs are being proposed and as such are being extended beyond their intended application.***

   The indices on which the biocriteria are based were calibrated from data collected at "least impacted" reference sites which included sites as small as 0.5 sq. mi. drainage area. The biocriteria are typically applicable down to ≈1.0 sq. mi. of drainage area based on the distribution of Ohio reference sites and demonstrated attainment of the biocriteria at these drainage areas. Although there is a greater likelihood of adverse impacts to aquatic life from the alteration of habitat and flows in streams of this size range, the potential to at least meet the WWH biocriteria in "low gradient" headwater streams of ≤1.0 sq. mi. was 24% statewide ranging from 11.8% of streams in the EOLP ecoregion to greater than 35% of streams in the IP and WAP ecoregions. For streams of 1.0-3.125 sq. mi. the statewide percentages of sites that can attain at least the WWH biocriteria was 25.4% which increased to 43.8% for streams of >3.125-10 sq. mi. in drainage. The variation in WWH attainment is often related to site-specific conditions which are best addressed by the reach-specific UAA framework that includes the consideration of restorability consistent with the EPA Water Quality Regulations. The proposed WQS state that *". . . except in circumstances documented through site-specific data collection and use attainability analyses, biological criteria shall not apply at stream*

> *locations where the drainage area is less than 1.0 square mile (Ohio Proposed Rule 3745-1-43)."* The analyses herein document that the Ohio EPA monitoring efforts are not only critical to the accurate characterization of aquatic life potential, but that a designation of the **DUs** at locations without such data will tacitly bypass the UAA process and lead to the almost certain loss of existing uses. Because the biocriteria will not apply to the proposed **DUs** <3.125 sq. mi., a minimum of 25% of these streams may well lose their existing uses that are consistent with a WWH or higher use. A continued reliance on the UAA framework applied to the determination of existing stream use potential as it has been conducted over the past 30 years by Ohio EPA would prevent the almost certain loss of stream quality and avoid eclipsing the existing use provision of the EPA Water Quality Regulations.

In addition to these findings, the proposed **DUs** and their elimination of biocriteria will lead to significant inaccuracies in the assessment of the quality of small streams. Not only will the inaccuracies described herein be propagated throughout the impairment listing process, there will likely be a corresponding disincentive to even monitor these small streams. This will not only lead to the propagation of both type I and type II assessment errors in the 303[d] listing process, but will be exacerbated by the inevitable substitution of extrapolative modeling approaches that would lack any validation by a bioassessment based UAA process.

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INTRODUCTION

Ohio EPA has been at the forefront of conducting and utilizing standardized biological monitoring of streams and rivers since the late 1970s. This work has served multiple purposes of environmental program management including the identification of point and nonpoint source impacts to the biological integrity goals of the Clean Water Act. As Ohio EPA gained expertise about the condition of streams and rivers and the mosaic of stressors that affected aquatic life through the 1980s they developed and refined standardized multimetric indices for fish and macroinvertebrates. These indices were designed to be sensitive across the range of river and stream sizes from principal rivers to headwater streams. They are responsive to the array of impacts affecting Ohio waters and are anchored in least impacted reference conditions across the Ohio landscape. Knowledge gained about natural and anthropogenic conditions throughout the state led to a refined classification of attainable biological assemblage expectations related to factors such as ecoregion, temperature (i.e., coldwater vs. warmwater), and watershed size (headwaters, wadeable, and boatable streams and rivers) which led to the calibration of indices to account for these factors. There is an implicit acknowledgement in this process that the inherent natural potential of rivers and streams can indeed vary. Historical alterations to the landscape for agricultural, industrial, and other human uses resulted in "baseline" conditions that can differ widely across Ohio. Some areas, partly because of their natural features (e.g., topographic relief, glacial deposits, groundwater inflows) were more resilient to these changes and as such retained higher quality biological attributes. Furthermore, direct alteration of stream habitats for drainage, flood control, and other uses resulted in comparatively "permanent" changes that are limiting to aquatic life. Taken together, these conditions and their legacy effects led to the development of *attainable* expectations for aquatic assemblages based on "least impacted" reference conditions that were translated into tiered aquatic life uses (TALUs) supported by numeric biocriteria in the Ohio WQS and as adopted in 1990.

This system of TALUs provides both protective and reasonably attainable goals for streams and rivers including those which meet or exceed the minimum Clean Water Act Sec. 101[a][2] goal (Exceptional Warmwater Habitat, **EWH**; Warmwater Habitat, **WWH**; Coldwater Habitat, **CWH**) and two tiers that are *below* the CWA minimum goal (Modified Warmwater Habitat, **MWH**; Limited Resource Water, **LRW**). Under the U.S. EPA regulations (40 CFR Part 131) designating these two latter uses requires a use attainability analysis (UAA). Ohio EPA developed and uses a systematic process for conducting UAAs that continues to be an integral, routine component of their watershed assessment process which serves as a national model.

Ohio EPA is proposing to add two new use categories - Upland Drainage (<3.1 sq. mi.) and Water Conveyance (>3.1 sq. mi.) which are herein referred to as Drainage Uses (**DU**) that would apply to "historically channelized" streams in Ohio. The **DU** designations would explicitly *exclude* the biocriteria and are also referred to as a "general uses". The Upland Drainage category is further delimited by stream gradient (Table 1a). According to the proposed rules (see Appendix 1) any watercourse designated for a **DU** (Upland Drainage or Water Conveyance) will exclude the biocriteria if they are considered a historically channelized (**HC**)[1] waterbody. Further, there is no upper limit of drainage area specified in the Water Conveyance use.

Table 1a. Stream gradient limitations for Upland Drainage streams by size.

Watershed Size Acres ($mi.^2$)	Percent Slope	Feet per Mile
≤1000 (1.56)	0.60	31.68
≤1500 (2.34)	0.40	21.12
≤2000 (3.13)	0.30	15.84

A goal of this analysis is to estimate the probable consequences of the loss of the explicit protections now offered by the Ohio biocriteria and the fundamental changes that would ensue under the proposed **DUs** in the way in which these streams would be designated under the scenarios that are implied by the proposed rules. This analysis provides; 1) estimates of the likely distribution of the currently applicable aquatic life uses (i.e., **EWH**, **WWH**, **MWH**, **LRW**) across unmonitored headwater streams based on existing data by ecoregion and Huc11 watershed; 2) the relationship between headwater stream habitat and primary nutrients to better understand the potential effects of management changes that are likely to occur if **DUs** are more widely applied in headwater streams; and, 3) a review the consequences of eliminating the biocriteria and hence relying on water chemistry indicators *alone* to assess attainment of aquatic life goals.

I. The Occurrence and Frequency of Tiered Aquatic Life Uses in Headwater Streams Subject to the Proposed Drainage Uses

Background and Methods

The quality of headwater streams, because they are numerous and intimately linked, is a fundamental linchpin to the condition of downstream water quality, sedimentation, and biological condition (Alexander et al. 2007; Gomi et al. 2002; Ohio EPA 2002; Meyer et al. 2007). Because headwaters are numerous and small, their role in the protection of downstream uses may be unrecognized (Gomi et al. 2002) and thus communicating their importance to landowners and the public can be difficult. In the Corn Belt regions of the Midwestern U.S. agricultural drainage is pervasive and its effects on headwater streams are equally pervasive and widespread (Blann et al. 2009).

Rankin (2003a) conducted an initial review of the condition of small streams and aquatic life use (ALUSE) potential in a review of the importance and function of headwater streams in Ohio. This study focused on a subset of the data that was analyzed herein to document that high quality fish and macroinvertebrate assemblages occur in even the smallest of Ohio headwater streams and to further

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[1] Historically channelized as defined in ORC 6111.12.

document the important functions of these waters to downstream uses. The present analysis utilized the existing Ohio EPA biological and habitat (QHEI) database through the year 2009 to examine the occurrence of Index of Biotic Integrity (IBIs) values that correspond to the Ohio TALUs and extrapolate these findings to currently *unmonitored and undesignated* streams that would be subject to the default application of the proposed **DUs**. The existing database provided to us by Ohio EPA during a project to recalibrate the Ohio IBI and ICI as continuous indices (Rankin 2010) was used for these analyses. A critical assertion of this analysis is that small streams that fall within the domain of the proposed **DUs** that are already designated under the Warmwater Habitat suite of uses could not be revised as that would violate the Existing Use[2] provision of the U.S. EPA Water Quality regulations. The intent of these analyses is to quantify the impact of the proposed **DUs** from a stream size, gradient, and regional perspective.

The "Channel Modification" attribute of the QHEI was used to identify streams that would qualify as historically channelized (**HC**) watercourses under the definition of that term. This QHEI attribute includes "natural" (no evidence of prior modifications), and three additional choices that imply various states of condition resulting from past or recent channel modifications (recovered, recovering, or recent/no recovery) based on visual evidence similar to that implied by the **HC** definition. The latter 3 categories were used to designate **HC** status for the purposes of this analysis. However, it may well be that streams identified as "natural" for the QHEI could be defined as **HC** under the definition in ORC 6111.12 as follows:

> *"If historical records cannot be located, then visual observations of side cast spoil banks in an upland landscape with supporting land surface elevation surveys may suffice as evidence that the watercourse was historically channelized."*

As such our analysis may well be conservative with regard to the potential reach of the **DUs**, but the results should apply nonetheless to any stream that actually meets the statutory definition of **HC**.

The analyses herein focused on the IBI for fish assemblages and the QHEI that is collected alongside. The existing TALUs for each stream from the Ohio WQS or the recommended use from Ohio Biological and Water Quality reports[3] were used. It appears that a primary purpose of the **DUs** is to remove a perceived obstacle to *carte blanch*e drainage maintenance, i.e., the current system of TALUs that applies to small streams in Ohio. An implied assertion of the **DU** proposal is that many of these small streams either do not nor cannot support biological assemblages consistent with **WWH** (at a minimum) and as such **DUs** will streamline drainage maintenance while purporting to protect aquatic life and water quality. For example, the Ohio DNR Rural Drainage Systems fact sheet (Ohio DNR 2008) states that for streams less than 3.125 sq. mi. an upland/headwater drainage way with biological data that confirms **WWH** ". . . ***is a fairly uncommon occurrence*** *. . .* " (emphasis ours). Thus an important goal of this analysis is to examine this and related assertions and premises thus quantifying the effects and risks of removing the biocriteria from these stream systems and to better understand whether there are spatial, stream size, and/or stream gradient related risks involved with this joint proposal.

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[2] 40 CFR Part 131.12[a][l].

[3] http://www.epa.ohio.gov/dsw/document_index/psdindx.aspx.

Influence of Proposed Stream Size Classifications

Stream size classification in terms of drainage area is a major aspect of the **DU** proposal thus it is important to understand how this factor affects aquatic life use potential. Table 1b shows the distribution of current Ohio aquatic life uses by Level IV ecoregion in Ohio. Tables 2 and 3 identify, from the available data, the number of streams statewide (Table 2) by Level III Ecoregion (Table 3) partitioned by the three **DU** stream size categories (<1.0 sq. mi., <3.125 sq. mi., and <10 sq. mi.). At the statewide level (Table 2) the data were analyzed separately for all streams and for those that are probable candidates for the **DU** because of evidence of historical channelization (**HC**). At the ecoregion level (Table 3) the analyses were limited to probable candidates for the **DU** due to **HC** and "low" (<3% slope) gradient as defined in the proposed **DU** procedure. The headwater streams that would comprise the proposed **DU** designation represent a substantial proportion of all stream miles in Ohio. Table 4 presents data on estimates from GIS[4] derived stream lengths by stream size category, statewide, and by Level 3 ecoregion. Streams <3.125 sq. mi. represent nearly 80% of all stream miles statewide and 72% to 80% within each of the Level III ecoregions of Ohio (Table 4).

Table 1b. Ohio stream miles by level III ecoregion and aquatic life use (column totals may not reflect rounding).

Aq. Life Use (ALU)	Statewide	WAP	So. MI/ No. IN Drift	EGL/ Hudson Lowland	Int. Plat.	ECBP	Erie Drift Plain	HELP
CWH	798	213	-	103	2.9	260	299	51.9
EWH/CWH	148	87.7	-	3.6	-	24.8	65.8	-
EWH	2,852	1,308	-	51.0	259	1,451	399	-
WWH/CWH	15.5	-	-	-	-	15.2	13.1	-
WWH	22,534	7,539	70.9	823	663	9,163	4,875	2,990
MWH	1,070	47.2	10.7	-	8.0	730	92.3	478
LWH	419	419	-	-	-	-	26.2	-
LRW	562	343	-	5.0	6.6	111	51.7	86.3
Total	28,399	9,957	81.6	986	940	11,754	5,821	3,516

Currently designated uses for headwater streams, including sites <1.0 sq. mi., encompass the full range of designated aquatic life uses in Ohio including Exceptional Warmwater Habitat (**EWH**), Coldwater Habitat (**CWH**), Warmwater Habitat (**WWH**), Modified Warmwater Habitat (**MWH**), and Limited Resource Waters (**LRW**; Table 2). At the statewide level, "low" gradient (<3% slope) headwater

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[4] Data provided by the Ohio Chapter of The Nature Conservancy. Watershed areas are from WtrShdAr.gdb and ALUs are from oepa_dsw_gis_data.gdb.

Table 2. Statewide frequency of aquatic life use designation by category of stream size, stream gradient and aquatic life use. Data from Ohio EPA from 1978-2009 where assessment data was available and aquatic life uses were assigned or recommended. QHEI data was used to distinguish among categories of average (map) gradient. High and low gradient sites do not sum to value at all sites because QHEI's were not available for all sites. Each count represents a sample pass at a site for a given date; unique stream provides a count for the number of different streams each total represents.

Location	Stream Size (sq. mi.)	Stream Gradient Category	Total Sites	EWH	CWH	WWH	MWH	LRW	Unique Streams
Statewide	≤1.0	All	375	5	19	264	28	59	248
	≤1.0 and HC		128	1	4	75	23	25	88
	≤3.1		1676	61	61	1270	125	159	896
	≤3.1 and HC		619	18	12	409	104	76	381
	3.1-10.0		3746	270	144	2965	262	105	1470
	3.1-10.0 & HC		1496	76	30	1127	218	45	789
	≤1.0	High Gradient, >3%	227	4	6	175	12	30	159
	≤3.1		972	49	40	781	17	85	604
	3.1-10.0		1328	159	62	1060	11	36	723
	≤1.0	Low Gradient, <3%	52	0	3	21	11	17	52
	≤3.1		358	2	5	208	89	54	186
	3.1-10.0		1625	64	30	1268	217	46	764

streams <1.0 sq. mi. are presently designated as **WWH**, **EWH**, and **CWH**. However, **MWH** designations are the most frequent for low gradient sites (Table 2) and are typically the result of channelization for agricultural drainage or other runoff conveyance purposes. Each of these have been vetted by a UAA process that considered several of the same factors included as default triggers in the **DU** proposal, but carefully weighing each one on an individual stream and stream segment basis as opposed to a default basis. This practice is essential because of the imperfect ability of physical factors alone to accurately predict aquatic assemblage condition or potential and as such meeting the intent of the existing use and attainable use clauses of the U.S. EPA regulations.

An examination of designated aquatic life uses by Level III ecoregion showed some expected patterns with the HELP ecoregion having the highest proportion of **MWH** and **LRW** designated streams and the IP and WAP ecoregions having comparatively fewer **MWH** designations (Table 3). The ECBP and the EOLP are intermediate in the distribution of **MWH** designated streams. The greatest variation across designated uses occurs in the ECBP which has the highest number of **EWH** and **CWH** designations in small headwater streams, but also has a substantial number of **MWH** and **LRW** designations.

Biological performance was also examined by stratifying IBI scores among five quality categories that correspond to the Ohio tiered aquatic life uses (TALUs) as follows:

Quality Category	**Corresponding TALU**	**IBI Range**	**Habitat Attributes**[5]
Excellent	EWH - Attains	≥46	Excellent
Good	WWH - Attains	≥36	Good
Fair – good habitat	WWH – Potential	30-34	Poor:Good <2:1
Fair – poor habitat	MWH – UAA required	30-34	Poor:Good >2:1
Poor	MWH - UAA required	22-28	Poor:Good >2:1
Very Poor	LRW - UAA required	≤20	Poor:Good >6:1

Table 3. Ecoregion frequency of occurrence of aquatic life use by category of stream size, stream gradient and aquatic life use for low gradient streams that are potential candidates for the Drainage Use because of historical channelization based on the QHEI channelization metric. Data is from Ohio EPA (1978-2009) where assessment data was available and aquatic life uses were assigned or recommended. QHEI data was used to distinguish among categories of average (map) gradient. Each count represents a sample pass at a site for a given date; unique stream provides a count for the number of different named streams included in each total.

Stream Size (sq. mi.)	**Total Sites**	**EWH**	**CWH**	**WWH**	**MWH**	**LRW**	**Unique Streams**
Huron Erie Lake Plain							
<1.0	10	0	0	6	2	2	5
<3.1	50	0	1	14	16	19	19
<10	212	0	2	115	63	28	94
Interior Plateau							
<1.0	1	0	0	1	0	0	1
<3.1	1	0	0	1	0	0	1
<10	31	0	0	31	0	0	10
Erie Ontario Lake Plain							
<1.0	17	0	0	2	6	9	6
<3.1	63	0	1	34	19	9	26
<10	305	2	2	232	51	18	123
Western Allegheny Plateau							
<1.0	1	0	0	1	0	0	1
<3.1	25	0	0	22	0	3	19
< 10	128	5	1	112	1	9	83
Eastern Corn Belt Plains							
<1.0	18	0	3	6	3	6	14
<3.1	142	2	3	68	52	17	82
<10	645	19	16	400	181	22	318

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[5] Quality or attributes ration that is "typically" associated with an IBI quality category and when habitat is the most limiting factor. Fair, poor, and very poor IBI scores can be due to non-habitat limiting factors and these are filtered during the UAA process.

Table 4. Estimates of miles of stream by Ohio ecoregion and stream size category. Data from the Ohio Chapter of The Nature Conservancy (column totals may not add due to rounding).

Size Class	Statewide	HELP	IP	EOLP	WAP	ECBP
>1000 mi.^{2}	750	199	37.7	8.2	311	183
500-1000 mi.^{2}	741	128	0.67	98.8	250	228
100-500 mi.^{2}	2,803	265	71.8	469	752	2,404
50-100 mi.^{2}	1,736	279	22.5	332	509	578
10-50 mi.^{2}	6,347	959	85.8	1,147	1,630	2,404
3.1-10 mi.^{2}	8,108	1,025	128	1,457	2,077	3,245
1-3.1 mi.^{2}	13,463	1,605	184	2,523	3,457	5,407
0.1-1 mi.^{2}	58,625	5,682	825	11,924	16,022	23,032
Total	92,573	10,141	1,356	17,959	25,007	37,482
% < 3.125 mi.^{2}	**77.9**	**71.9**	**74.4**	**80.4**	**77.9**	**75.9**

The two fair categories are comprised of a mix of sites that are impaired from WWH, some of which are probably restorable and others that have poor habitat attributes due to legacy or maintenance activities that *may* preclude attainment of the **WWH** biocriteria. Again, the UAA process first determines the causes of the impairment and then whether those impairments can be resolved and if the associated activities preclude WWH due to factors cited in the EPA Water Quality Regulations[6].

The **DU** proposal employs stream size and gradient thresholds to determine which DUs apply and also the drainage and mitigation practices that can be applied in each. The drainage area criteria in the **DU** proposal are not biologically based, but rather are based on “hydrological BPJ” that emphasizes the role of gradient in agricultural drainage. These factors are also important in determining fish assemblage potential and likewise influence the result of habitat alterations on aquatic life. It is important then to understand what the “error” or misclassification rate would be by the **DU** proposal simply assuming that stream size and gradient would in effect rule out a **WWH** or better aquatic life use designation.

The statewide analysis of IBI and QHEI show that all of the **DU** stream size categories have substantial numbers of sites that either attain or are capable of attaining the **WWH** use tier or better. Table 5 summarizes the frequency of sites by IBI quality ranges and stream size for all gradient categories and whether or not they would be candidates for a **DU** because of **HC**. We combined sites with Excellent, Good, and Fair$^{\text{Good Habitat}}$ **IBIs** into a column titled “% with at least **WWH** potential” as an estimate of the proportion of **DU** subject streams that are capable of supporting at least a **WWH** aquatic life use under the current Ohio UAA practices. For streams <1.0 sq. mi., 33% of sites have at least **WWH** potential and from 1.0-3.125 sq. mi. nearly 50% of streams have at least **WWH** potential. These percentages are likely underestimates because the data also includes sites that are impaired by pollutant sources (e.g., manure runoff, urban runoff, and toxicants) that caused these sites to perform in the Poor or Very Poor categories. As such these would not qualify for a use less than WWH use because they are due to pollutants, are regulated sources, and are thus restorable by CWA management programs.

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[6] 40CFR Part 131.10[g][1-6]

When sites that are candidates for **DU** with evidence of **HC** (Table 6) are isolated, a similar pattern emerged with 34.7% of <1.0 sq. mi. sites and 41.5% of larger sites exhibiting at least **WWH** potential. These results are only a slight change from including all sites and represent the restoration of attainable uses in headwater streams that show evidence of **HC** in the QHEI. Table 7 shows streams that are **HC**

Table 5. Number and percent of sites in Ohio (Statewide, all gradient ranges) by fish IBI scoring range (headwater site type) for streams ≤1.0 sq. mi., streams 1.0-3.13 sq. mi., and streams >3.13-10.0 sq. mi. in drainage area. The column "% with at least ***WWH*** *Potential" is the sum of* ***EWH*** *IBIs,* ***WWH*** *IBIs, and Fair IBIs with good habitat.*

Stream Size	Number of Sites	% With at Least WWH Potential	Attain EWH IBI		Attain WWH IBI		Fair IBI (Good Habitat)		Fair IBI (Poor Habitat)		Poor IBI		Very Poor IBI	
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
≤1.0 mi.^{2}	417	33.8	44	10.6	84	20.1	13	3.1	3	0.7	93	22.3	125	30
1.0-3.13 mi.^{2}	1356	49.6	272	20.1	358	26.4	42	3.1	4	0.3	322	23.7	199	14.7
>3.13-10 mi.^{2}	3950	55.6	895	22.7	1167	29.5	136	3.4	25	0.6	868	22	338	8.6

Table 6. Number and percent of sites in Ohio (Statewide, all gradient ranges) by Fish IBI scoring range (headwater IBI) for streams < 1.0 sq. mi., streams 1.0-3.13 sq. mi., and streams >3.13-10.0 sq. mi. in drainage size panels that are potential candidates as ***DC*** *for* ***HC*** *streams. The column "% with at least* ***WWH*** *Potential" is the sum of* ***EWH*** *IBIs,* ***WWH*** *IBIs, and Fair IBIs with good habitat.*

Stream Size	Number of Sites	% With at Least WWH Potential	Attains EWH IBI		Attains WWH IBI		Fair IBI (Good Habitat)		Fair IBI (Poor Habitat)		Poor IBI		Very Poor IBI	
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
≤1.0 mi.^{2}	147	34.7	10	6.8	29	19.7	12	8.2	3	2.0	31	21.1	44	29.9
1.0-3.13 mi.^{2}	531	41.5	66	12.0	116	21.8	39	7.3	2	0.4	154	29.0	100	18.8
>3.13-10 mi.^{2}	1587	50.9	271	17.1	404	25.5	131	8.3	19	1.2	430	27.1	179	11.3

Table 7. Number and percent of sites in Ohio (Statewide, low gradient) by Fish IBI scoring range (headwater IBI) for streams < 1.0 sq. mi., streams 1.0-3.13 sq. mi., and streams >3.13-10.0 sq. mi. in drainage size that are potential candidates as "historically channelized streams" and that have gradient values < 15.85 ft./mi (<3% slope). The column "% with at least ***WWH*** *Potential" is the sum of* ***EWH*** *IBIs,* ***WWH*** *IBIs, and Fair IBIs with good habitat.*

Stream Size	Number of Sites	% With at Least WWH Potential	Attains EWH IBI		Attains WWH IBI		Fair IBI (Good Habitat)		Fair IBI (Poor Habitat)		Poor IBI		Very Poor IBI	
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
≤1.0 mi.^{2}	50	24.0	2	4.0	4	8.0	6	12.0	2	4.0	10	20.0	19	38.0
1.0-3.13 mi.^{2}	247	25.4	10	4.0	30	12.1	23	9.3	0	0.0	92	37.2	70	28.3
>3.13-10 mi.^{2}	1080	43.8	110	10.2	250	23.1	113	10.5	15	1.4	349	32.3	137	12.7

Table 8. Number and percent of low gradient (<3% slope) sites in Ohio by IBI scoring ranges (headwater site type) for streams ≤1.0 sq. mi., streams 1.0-3.13 sq. mi., and streams >3.13-10.0 sq. mi. that also qualify as ***HC****. The column "% with at least* ***WWH*** *Potential" is the sum of* ***EWH*** *IBIs,* ***WWH*** *IBIs, and Fair IBIs with good habitat. The HELP ecoregion results were assessed using both the HELP ecoregion biocriterion (IBI=28) and the ECBP ecoregion biocriterion (IBI=36); both include the non-significant departure allowance for the IBI.*

Stream Size	No. of Sites	% With at Least WWH Potential	Attains EWH IBI		Attains WWH IBI		Fair IBI (Good Habitat)		Fair IBI (Poor Habitat)		Poor IBI		Very Poor IBI	
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
HELP Ecoregion[1]														
≤1.0 mi.^{2}	14	21.4	0	0.0	3	21.4	na	na	na	na	3	21.4	4	28.6
1.0-3.13 mi.^{2}	38	7.9	0	0.0	3	7.9	na	na	na	na	8	21.1	26	68.4
>3.13-10 mi.^{2}	160	29.4	1	0.6	46	28.9	na	na	na	na	54	33.8	49	30.6
HELP Ecoregion[2]														
≤1.0 mi.^{2}	14	21.4	0	0.0	1	7.1	2	14.3	0	0.0	3	21.4	4	28.6
1.0-3.13 mi.^{2}	38	5.2	0	0.0	1	2.6	1	2.6	0	0.0	8	21.1	26	68.4
>3.13-10 mi.^{2}	160	17.5	1	0.6	8	5.0	19	11.9	0	0.0	67	41.9	49	30.6
IP Ecoregion														
>3.13-10 mi.^{2}	31	35.5	4	12.9	7	22.6	0	0.0	0	0.0	13	41.9	2	6.5
EOLP Ecoregion														
≤1.0 mi.^{2}	17	11.8	0	0.0	0	0.0	2	11.8	0	0.0	4	23.5	8	47.1
1.0-3.13 mi.^{2}	52	25.0	1	1.9	5	9.6	7	13.5	0	0.0	23	44.2	9	17.3
>3.13-10 mi.^{2}	236	45.4	20	8.5	67	28.4	20	8.5	6	2.5	64	27.1	34	14.4
WAP Ecoregion														
1.0-3.13 mi.^{2}	21	28.6	1	4.8	4	19.0	1	4.8	0	0.0	9	42.9	6	28.6
>3.13-10 mi.^{2}	105	56.2	14	13.3	3	28.6	15	14.3	2	1.9	24	22.9	14	13.3
ECBP Ecoregion														
≤1.0 mi.^{2}	17	35.4	2	11.8	2	11.8	2	11.8	1	5.9	3	17.6	7	41.2
1.0-3.13 mi.^{2}	122	30.3	6	4.9	19	15.6	12	9.8	0	0.0	45	36.9	28	23.0
>3.13-10 mi.^{2}	477	47.5	56	11.7	119	24.9	52	10.9	5	1.0	161	33.0	35	7.3

and with a <3% slope (<15.85 ft./mi. gradient). There was a slight decrease in the percent of sites with at least **WWH** potential (24% of <1.0 sq. mi. streams and 25.4% of 1.0-3.125 sq. mi. streams), but the data still suggest that fully 25% of these small headwater sites will not have their potential aquatic life uses protected under the proposed **DU** from a Statewide perspective.

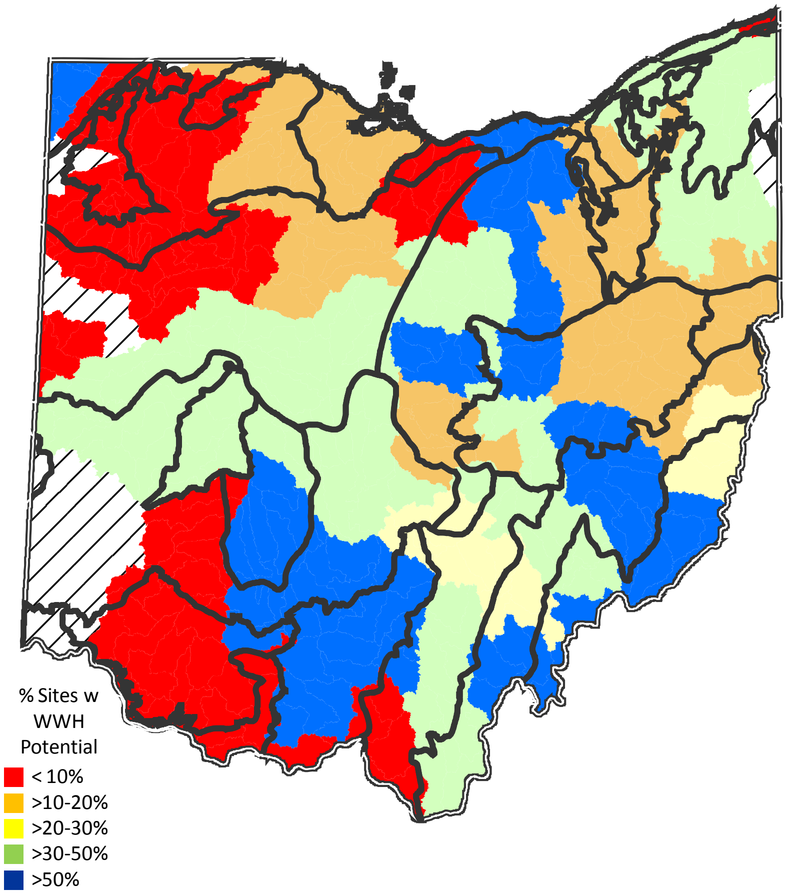


*Figure 1. Map showing the frequency of WWH potential for small headwater streams that qualify as **HC** by Huc-8 watershed in Ohio. Hatched watersheds have fewer than 3 **HC** sites < 3.1 sq. mi. in the Huc-8 watershed. Black lines represent Level IV subregions.*

The **DU** proposal applies on a statewide basis; however, habitat alteration via channelization has occurred unevenly across the state. Impairment statistics by Level III ecoregion were determined for low gradient (<3% slope) **HC** sites (Table 8) to reveal any regional variation in habitat related effects on the attainability of a **WWH** or better aquatic life use. The Huron Erie Lake Plain (HELP) ecoregion has experienced the most extensive historical stream alterations of any Ohio ecoregion resulting from the legacy impacts of agricultural drainage. This also extends into the low gradient and historically wetter soil subregions of the Eastern Corn Belt Plains (ECBP) ecoregion. Stream channelization to enhance agricultural drainage has been less extensive in the Erie-Ontario Lake Plain (EOLP) and rare in the Interior Plateau (IP) and Western Allegheny Plateau (WAP) ecoregions.

Because of the pattern of habitat alterations and stream gradients by ecoregion there are very few low gradient **HC** sites in streams <1.0 sq. mi. in the IP and WAP ecoregions. The WAP is unglaciated and most small headwater streams originate in areas of high relief. The IP ecoregion occupies a smaller area of Ohio, has high relief, and consists almost entirely of high gradient, bedrock streams and as a result there were no low gradient **HC** streams in the 1.0-3.125 sq. mi. category. In contrast the HELP ecoregion is clearly where the majority of low gradient small streams occur. However, there are streams subject to the **DU** proposal that have WWH potential in this ecoregion. The results of the analyses show that application of the proposed **DU** in the IP, WAP, EOLP and ECBP ecoregions would result in the widespread loss of both attaining and potential to attain **WWH** or better streams. The results also suggest that a strong geographic stratification of habitat alteration is an issue to consider in the protection of existing uses. Figure 1 illustrates ranges of **WWH** aquatic life use potential in small, low gradient (<10 ft./mi.) headwaters (<3.125 sq. mi.) that are candidates as **HC** sites at the Huc-8 watershed scale. In this analysis a 10 ft./mi. gradient threshold was used in lieu of the BPJ derived 15.85 ft./mi. threshold for **DU** because analyses that appear later in this report show that 10 ft./mi. would be a more appropriate and biologically relevant gradient threshold. Figure 2 illustrates patterns in **WWH** potential for all headwater and all gradient streams <10 sq. mi. at the Huc-11 watershed scale. All sites were used in this map because of sample size limitations at the Huc-11 watershed scale. These maps, when extrapolated to unmonitored (and potentially undesignated) streams, illustrate the geographic variation in the potential of small headwater streams to attain **WWH** or better. The dark outlines on the maps represent Level IV ecoregions and these were added because Level III ecoregions do not provide a sufficiently resolute stratification about where the proposed **DU** would be of the most consequence to aquatic life use designations in Ohio. Certain subregions within the Level III HELP ecoregion and the northern portions of the ECBP are where the **DU** seems to be of the most frequent consequence. The differences between Figures 1 and 2 reflect the cumulative extent of agricultural drainage effects over the past several decades and include flow alterations in addition to channel modifications (also see Appendix 1). Some of the patterns evident in Figure 1 at <3.125 sq. mi. still remain in the HELP ecoregion, but diminish when the size threshold is increased to 10 sq. mi. in other parts of the ECBP (e.g., Loamy, High Lime Till Plains [55b] subregion and

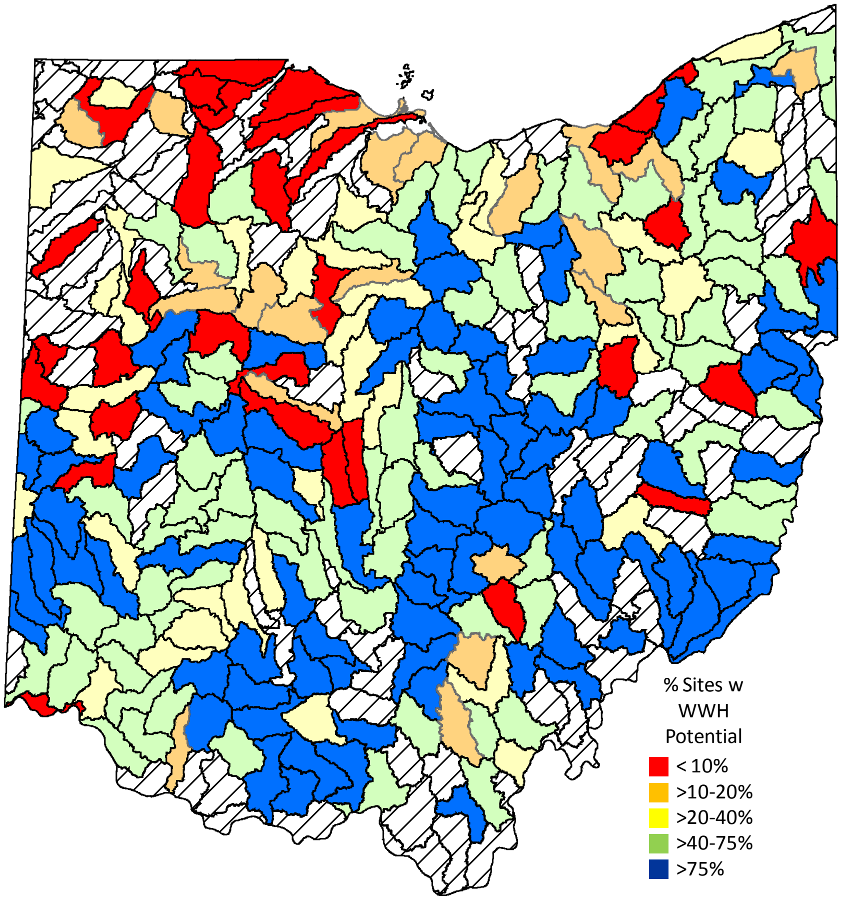


Figure 2. Map of the percent WWH attainment potential of small headwater streams (<10 sq. mi.) in Ohio by Huc 11 watershed. Hatched watersheds have less than 3 sites ≤3.125 sq. mi. in a Huc-11 watershed. Light green shaded watersheds show ≤10% attainment potential of at least WWH; dark green >10-20% WWH potential; light blue >20-40% WWH potential; dark blue >40- 75% WWH potential; and, magenta >75% WWH potential.

pre-Wisconsinan Drift Plains [55d] subregions in southwest Ohio). Even so there is enough variation in **WWH** attainment potential that stratifying the **DU** proposal to selected Level IV subregions would still incur use designation errors especially for sites that currently attain or are very close to attaining **WWH** or better.

Influence of Proposed Stream Gradient Classifications

The **DU** proposal identifies three stream gradient thresholds under which the **DUs** for **HC** streams would apply (see Table 1a). These arose from a study of the conflicts between the current system of aquatic life uses and agricultural drainage (Ohio DNR 2008). Conceptually, higher gradient streams have a higher probability of recovering naturally from habitat alterations because the increased hydrological power during subsequent high flow events more rapidly reforms natural habitat attributes. This phenomenon has been a major consideration in the Ohio UAA process over the past 30 years. The DU proposal would instead impose what are in effect “BPJ derived” thresholds for gradient and become a default trigger along with drainage area to determine when a **DU** would apply. The **DU** proposal also includes streams with gradient that exceeds the default thresholds by either prior consultation with Ohio EPA or the implementation of an alternative to the traditional trapezoidal channel design such as a two-stage ditch. Because gradient is a major factor in the **DU** proposal and the implications of these thresholds to eclipse **WWH** or better aquatic life potential these thresholds were likewise examined.

The influence of stream gradient on habitat and biological assemblages is important and is already incorporated in the scoring ranges of the QHEI gradient metric (Rankin 1987, 1995; Ohio EPA 2006). The QHEI thresholds consider gradient <5 ft./mi. (0.09% slope) as being “low” and 1.0 ft./mi. (0.019% slope) as being very low (Ohio EPA 1996). These values were derived by examining fish assemblage attributes along stream gradients at varying drainage sizes and primarily for streams >1.0 sq. mi. Stream and river size is a co-factor in determining the QHEI gradient score and it incorporates the gradient definitions from Trautman (1981). However, these thresholds were never intended to imply that low gradient streams are inherently incapable of attaining the **WWH** biocriteria. However, gradient is an important consideration of the Ohio UAA process since low gradient streams will either require physical intervention or take longer to naturally recover from anthropogenic modifications as these result in an impairment of the **WWH** use designation.

It has been recognized that low gradient streams, with less power to expel fine sediments and reform good habitat attributes, can be more susceptible to the adverse impacts of land uses such as row crop agriculture, surface mining, silviculture, and urban development. The proposed **DU** specifies three distinct stream gradient thresholds for **HC** and varying by stream size as follows:

> *“The upland drainage use designation shall apply to all water body segments that:*
>
> *i. Are HC watercourses;*
> *ii. Drain less than 3.1 square miles; and*
> *iii. Have average gradients no greater than 0.6 per cent at watersheds up to one thousand acres, no greater than 0.4 per cent at watersheds up to fifteen*

> *hundred acres and no greater than 0.3 per cent at watersheds up to two thousand acres."*

Although the proposed rules do not specify the origin of these stream gradient thresholds, they are consistent with analyses performed by the Ohio DNR, Division of Soil and Water Conservation regarding the likelihood of the need for a 404 permit from the U.S. Army Corps of Engineers and 401 water quality certification from Ohio EPA (Ohio DNR drainage use presentation; Ohio DNR 2008).

To illustrate the potential impact of these thresholds on aquatic life use attainment and potential, the probability of aquatic life use attainment changing with increasing stream gradient was analyzed. Twenty (20) equally sized bins of data for streams <10 sq. mi. were arrayed along the average stream gradient included in the QHEI at each site. Again, the 10 sq. mi. threshold was used in lieu of the proposed **DU** thresholds because it was shown to be biologically relevant. For each of these bins the percentage of sites attaining WWH (i.e., IBI ≥36) was determined. A locally weighted Least Squares Error (Lowess) regression curve was fitted to the results in order to reveal any patterns in **WWH** attainment with stream gradient (Figure 3). The red dashed vertical lines represent the gradient threshold revealed by the Lowess curve for each stream size. Figure 3 represents statewide data plotted separately for streams <1000 acres (1.56 sq. mi., upper), <1500 acres (2.34 sq. mi., middle) and 2,000 acres (3.13 sq. mi., lower) drainage areas. These results show that 22-43% of sites with stream gradients below the proposed **DU** thresholds attained the **WWH** or better aquatic life use (Figure 3). The results further show that the probability of attainment of **WWH** declines to 10% at a gradient <10 ft./mi. at all sizes of small headwater streams. Again, these results present a worst-case scenario as pollutant and other non-habitat impacts are likely included in the results.

To reduce potential bias against habitat altered sites and to more accurately assess "natural" limitations to aquatic assemblages that are implied by the proposed **DU** stream gradient thresholds, sites that had habitat considered to be of "Good" quality (i.e., QHEI ≥55; Ohio EPA 2006) were isolated to determine the probability of attaining WWH (i.e., IBI ≥36) vs. stream gradient (Figure 4). For sites with Good quality habitat, the probability of attaining a **WWH** IBI score ranged between 50% and 58% for the gradient thresholds. As a result the proposed DU gradient thresholds would result in at least *50% or more* of streams with Good habitat being subjected to stream management practices under the proposed **DU** and draft Drainage Manual (Ohio DNR 2008). Furthermore, without the vetting of other potential stressors via the UAA process additional streams with the potential to eventually attain WWH or better would become vulnerable as well.

To examine whether geographic location influences the gradient thresholds a similar analysis was stratified by Level III ecoregion by examining the probability of attaining the ecoregion-based IBI biocriteria for streams with slopes less than and greater than the 3% (15.85 ft. mi.) **DU** threshold. There was a difference in the probability of attainment between sites above and below the 3% slope threshold in the EOLP and ECBP ecoregions, but an insufficient number of higher slope sites to derive the same in the HELP ecoregion (Figure 5). The probability of attainment with stream size for sites above and below the 3% slope cutoff in the IP and WAP ecoregions was much smaller. With the exception of the HELP

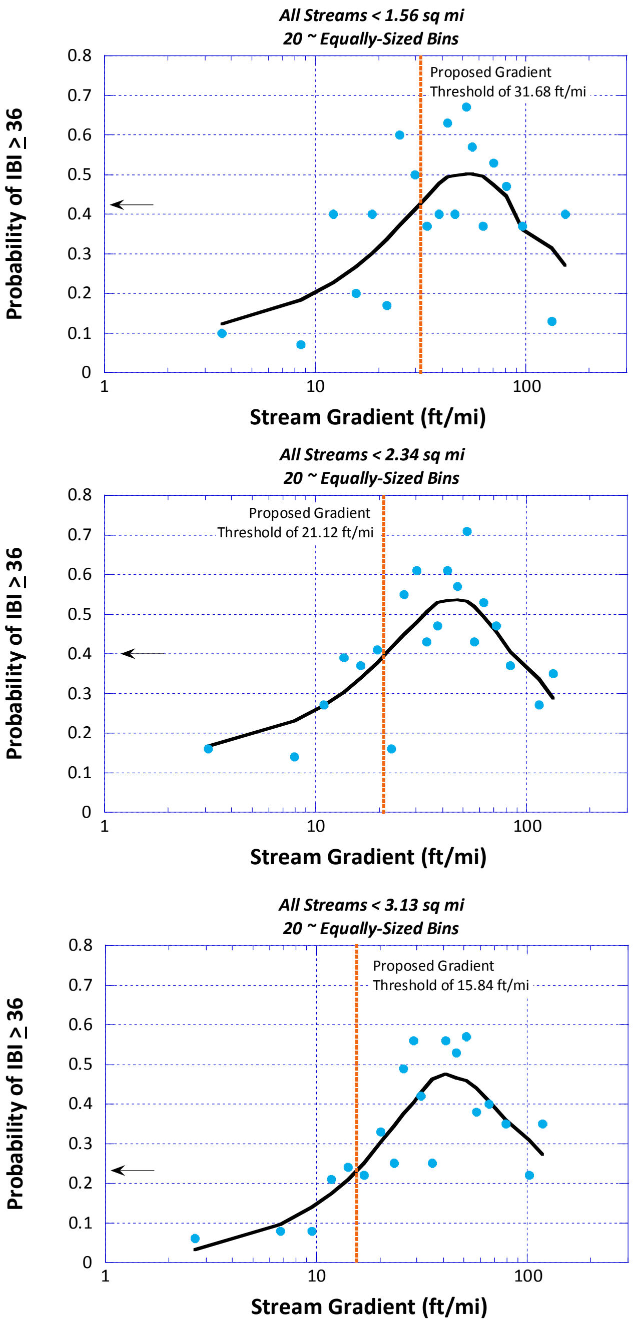


Figure 3. Plots of the midpoint of stream gradient (20 equally sized bins) vs. the probability of attaining WWH (IBI ≥36) in Ohio streams <1000 acres (upper), 1500 acres (middle), or 2000 acres (lower). Curves reflect Locally Weighted Regressions (Lowess). Points where proposed thresholds intercept the Lowess curves are denoted by an arrow on the Y-axis.

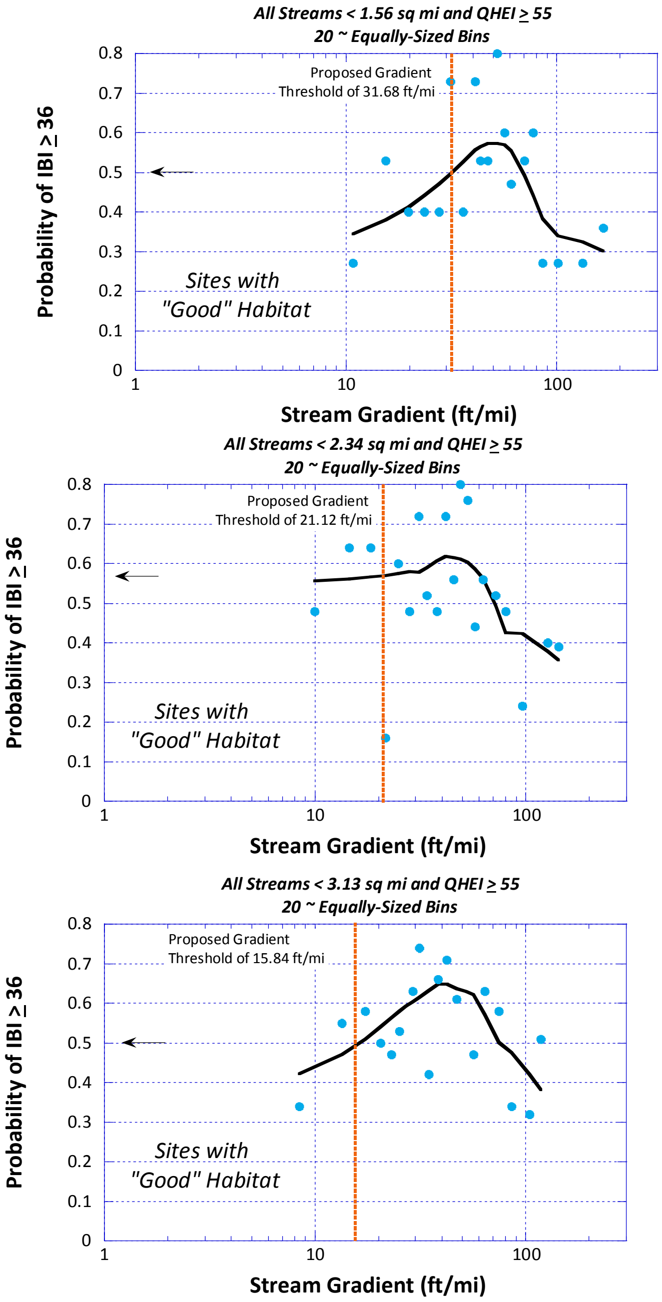


Figure 4. Plots of the midpoint of stream gradient (20 equally sized bins) vs. the probability of attaining WWH (IBI ≥36) in Ohio streams of <1000 acres (upper), 1500 acres (middle), or 2000 acres (lower) for sites with a QHEI of ≥55 (Good quality). Curves reflect Locally Weighted Regressions (Lowess). Points where proposed thresholds intercept the Lowess curves are denoted by an arrow on the Y-axis.

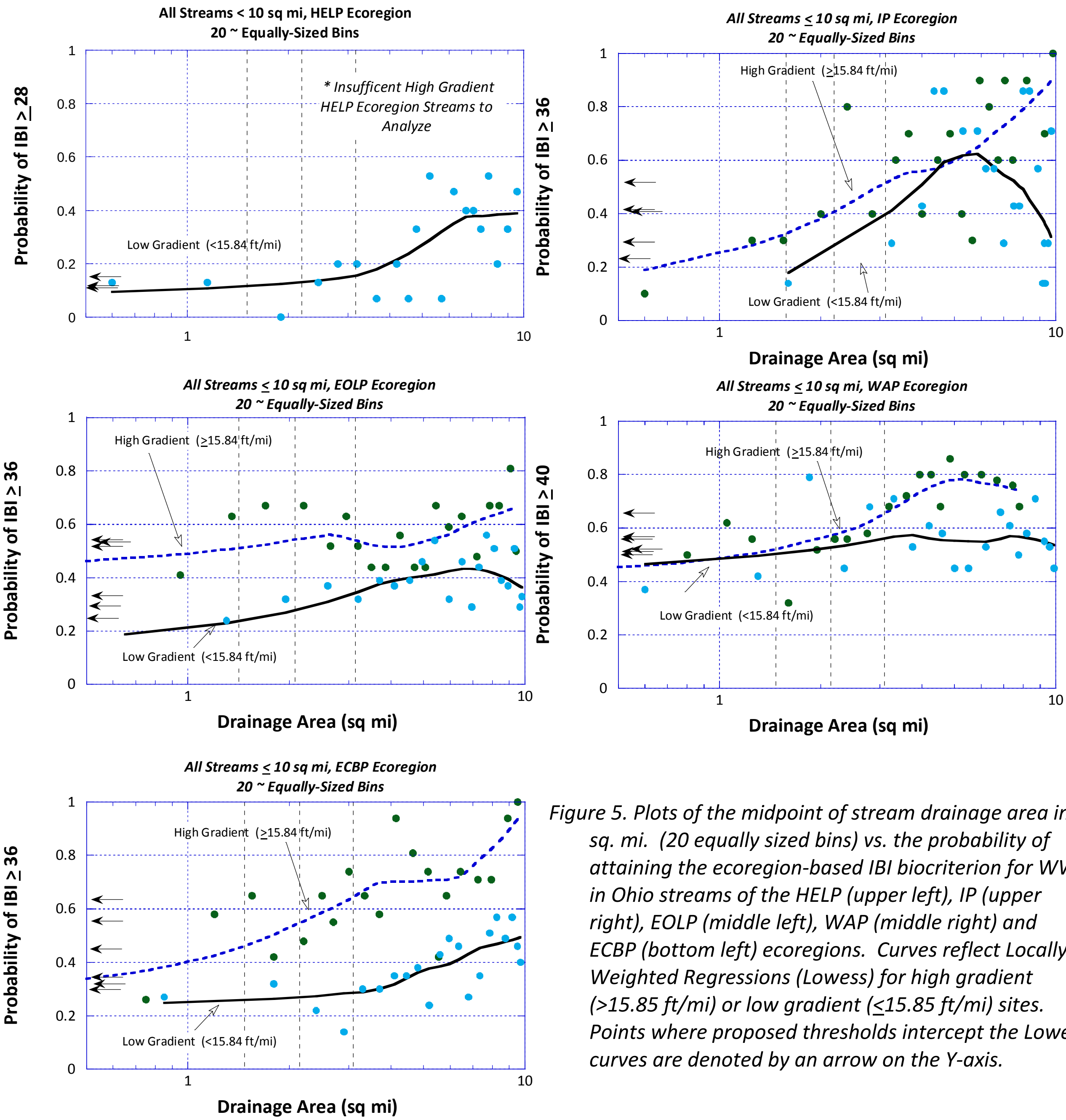


Figure 5. Plots of the midpoint of stream drainage area in sq. mi. (20 equally sized bins) vs. the probability of attaining the ecoregion-based IBI biocriterion for WWH in Ohio streams of the HELP (upper left), IP (upper right), EOLP (middle left), WAP (middle right) and ECBP (bottom left) ecoregions. Curves reflect Locally Weighted Regressions (Lowess) for high gradient (>15.85 ft/mi) or low gradient (≤15.85 ft/mi) sites. Points where proposed thresholds intercept the Lowess curves are denoted by an arrow on the Y-axis.

ecoregion, which has IBI attainment probabilities of ~10-20% in small headwaters (<3.125 sq. mi.), sites in other ecoregions had low gradient **WWH** IBI attainment probabilities of >20%. Stream gradient can be a useful variable for assessing the potential for recovering natural habitat attributes over time (and without intervention) because of the link between hydraulic power and the reformation of good habitat attributes. Hydraulic power is a product of gradient and flow and is typically calculated at channel forming flows such as the 2-year high flow recurrence interval (Mecklenburg and Fay 2011). To protect existing aquatic life uses there needs to be a biologically derived linkage between slope and aquatic life use attainability. The analyses herein suggest that the slope thresholds in the proposed **DU** would exclude many streams that have the potential to attain **WWH** and abrogate existing use as a result.

These analyses support continuing the use of biologically derived gradient thresholds in the UAA process.

II. The Influence of Headwater Stream Channel Condition on Nutrients

Implicit in the **DU** proposal is the underlying assumption that chemical water quality criteria will be attained at the "pour point" of 3.125 sq. mi. and where the biocriteria would no longer be the arbiter of aquatic life use attainment. This is in addition to the inherent assumptions of the **DU** proposal that streams <3.125 sq. mi. and with "low" gradient (<3% slopes) are not capable of attaining **WWH** or better. The focus of this part of the analysis is on the assumption that small headwater streams can be managed in a way that meets nutrient criteria and also limits the export of excessive nutrients to downstream reaches where the **WWH** suite of uses would still apply. This assumption includes the acceptance of trapezoidal or two stage channels as acceptable best management practices under the proposed **DUs** and the Ohio DNR drainage manual.

Current Knowledge about Nutrients and Stream Habitat

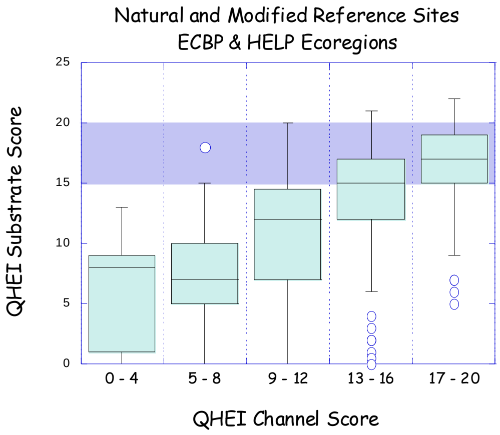


Figure 6. Box-and-whisker plot of QHEI channel score vs. the QHEI substrate score from least impacted natural and channel modified reference sites in the ECBP and HELP ecoregions of Ohio (after Rankin 2004).

Although there is an extensive base of literature relating nutrient runoff to land uses, there is a much smaller base of literature linking instream nutrient delivery, transformation, and assimilation to habitat conditions related to channelization and drainage. The influence of nutrients on aquatic life is complex and is simultaneously influenced by habitat, flow, land use, and geomorphic conditions (Miltner and Rankin 1988; Rankin 2004; Miltner 2010). First and second order headwater streams play a key role in controlling nutrient, water, sediment, and organic material export to higher order streams. Alexander et al. (2007) found that . . . "first-order headwaters contribute approximately 70% of the mean-annual water volume and 65% of the nitrogen flux in second-order stream systems." Studies have shown that headwaters are primary zones for nitrogen loss in watersheds because of their greater benthic surface area relative to flow volume and close connections to hyporheic zones (Alexander et al., 2000; Peterson et al., 2001). The loss of coarse headwater substrates results in the reduced instream processing of nutrients. In Ohio, for example, Rankin (2004) found that stream channel alterations measured by the QHEI were strongly associated with a decrease in coarse substrates (Figure 6). Altered stream channels (*e.g.*, as exemplified by the **DU** acceptable trapezoidal channels) are nearly always associated with fine materials such as clayey silts and embedded substrates both of which result in reduced QHEI substrate scores (Figure 6). These poor quality substrate characteristics influence the ability of headwater streams to remove and sequester nutrients and hyporheic exchanges as well. This is supported by research on the nutrient and chemical dynamics of ditches in the Portage River by

Richards et al. (2008) who concluded that ". . . biological processing is not very effective in these drainage ditches, *or at least that it is not efficient enough to keep up with new inputs along the length of the ditch."* Ohio EPA (1999) found a similar relationship between stream habitat and total phosphorus, the implication being that degraded headwater habitat results in biological assemblages that are either less efficient or wholly inefficient at sequestering phosphorus thus preventing excess amounts from being transported downstream.

There is substantial correlative evidence that channelized streams are more likely to export higher nutrient loads compared to natural stream channels. Studies of nutrient export in small watersheds have documented that small streams in forested catchments typically have very low nutrient exports, whereas similarly sized modified and drainage altered steams can have nutrient concentrations several orders of magnitude higher partly because these altered systems bypass riparian flow paths thus inhibiting nutrient uptake and retention in these areas (Peterjohn and Correl 1984). Yarbo et al. (1984) found that exports of nitrogen were greater from channelized streams than unaltered wetland streams. They concluded that ". . . changes in local groundwater hydrology and stream morphology associated with channelization appeared to have greater effect on nutrient exports than simply the loss of bordering forested floodplain". Some researchers found that adding coarse woody debris in headwater streams increased transient storage of flow and also increased nutrient assimilation (Robert et al. 2007). Woody debris is typically removed to improve water flow in drainage channels and woody growth along the banks is eliminated by cutting and herbicide applications. An impetus for the proposed **DU** is to make this type of drainage way maintenance of **HC** streams easier and also to alter such streams that have over time regained woody debris, woody riparian vegetation, and channel characteristics that increase "transient storage" of flows and nutrients. The analyses in Part I that showed **WWH** attainment or the potential to attain **WWH** in a large percentage of **HC** streams was due solely to the natural recovery of riparian and instream habitat attributes that were followed by biological improvements.

Empirically Derived Nutrient, Habitat, and Biological Assemblage Associations

We examined the linkage between Ohio biological assemblage data, habitat data, and nutrient concentrations in Ohio streams that was collected by Ohio EPA over the past ~30 years. The analyses are correlative and some of the streams are affected by multiple stressors. Nevertheless, the sheer size of the database can provide directional evidence about whether streams with poor QHEI scores are associated with elevated nutrient concentrations as is suggested by the preceding literature review. If so, it would reveal how effectively headwater streams that are subject to traditional drainage practices and maintenance might function in protecting downstream reaches from excessive nutrient loadings. This would also test a major assumption of the **DU** proposal that chemical water quality can be maintained.

Because of the open nature of stream systems it was expected that some of the strongest patterns might occur at the watershed scale. To explore this mean IBI scores, mean QHEI scores, and mean total phosphorus (TP), mean total Kjeldahl nitrogen (TKN), and mean total nitrate (NO_3) concentrations were examined at the Huc-11 watershed scale for stream sites of <3.0 sq. mi., <5.0 sq. mi., <20 sq. mi., and <50 sq. mi. drainage areas (Figures 7-9).

Total Phosphorus

There was a pattern of decreasing TP with increasing habitat (QHEI) at the Huc11 watershed scale although the relationship of the mean value was rather variable and weak (Figure 7, left). This is not necessarily surprising since TP can originate from overland transport and bank erosion, livestock wastes, and point sources. The association between TP and the IBI was stronger (Figure 7, right). Although the relationship reflected in the mean regression was rather weak, there appears to be a lower threshold relationship between the QHEI and TP, what may be termed as a “floor” relationship as reflected by the dashed line drawn by eye on each graph. The substantial variation in TP at the watershed scale could be related to point and other agricultural sources (e.g., AFOs) of TP that would overwhelm any relationship in some watersheds. The floor relationship suggests that lower TP levels are more typically restricted to watersheds with good average habitat quality and that sites with poor habitat usually have higher TP. The raw data was examined using site-specific QHEI and mean TP and plotting the probability of low TP values (<0.10-0.20 mg/l) vs. QHEI (midpoints of bins of equal sample size). A Lowess smoothing regression for QHEI and TP is illustrated in Figure 10. The probability of observing the lowest TP value increases sharply with increasing QHEI scores which shows an inverse association between habitat quality and TP in headwater streams that would be subject to the proposed **DU**.

Site-specific TP was examined by each of the four channel condition choices of the QHEI channel metric (natural, recovered, recovering, and recent or no recovery) for headwater streams <3.0 sq. mi., <5.0 sq. mi., and <20 sq. mi. (Figure 11). There was no evident relationship at the 20 sq. mi. threshold, but stronger ones at the 3.0 and 5.0 sq. mi. thresholds. This suggests that multiple sources of TP may be influencing streams by the time they reach the 20 sq. mi. size threshold (i.e., other than the channel condition at that scale) as the link between site-specific channel condition and instream TP seems strongest at the smaller drainage areas. This agrees with the results of research performed on the trophic functioning of streams that suggests headwaters with high substrate surface area to water volume ratios are the most effective at removing nutrients (Peterson et al. 2001). Exploratory regression tree analyses of habitat and TP data in the ECBP and HELP ecoregions showed low TP was associated with coarse substrates that are typical of natural channels (see Figure 5) and higher TP was associated with low QHEI pool scores and finer substrates which are typical of channelized streams (Rankin 2004).

Total Kjeldahl Nitrogen (TKN)

TKN measures the organic forms of nitrogen (algal, particulate organic matter) and is another signature of nutrient enrichment. TKN showed the strongest floor association with QHEI and the strongest association with the IBI (Figure 12). An Ohio study of the relationship between habitat, nutrients, and biological assemblages also showed a strong relationship between TKN and biological assemblage measures in headwater and wadeable streams of the ECBP and HELP ecoregions (Rankin 2004). As with TP there was a pattern of decreasing TKN with increasing QHEI scores at the Huc11 watershed scale (Figure 8, left). The association between TKN and the IBI was the strongest of any of the nutrient indicators (Figure 8, right). A plot of the probability of low TKN values (<0.3 or <0.5 mg/l) vs. QHEI (midpoints of bins of equal sample size) illustrated that the probability of observing the lowest TKN

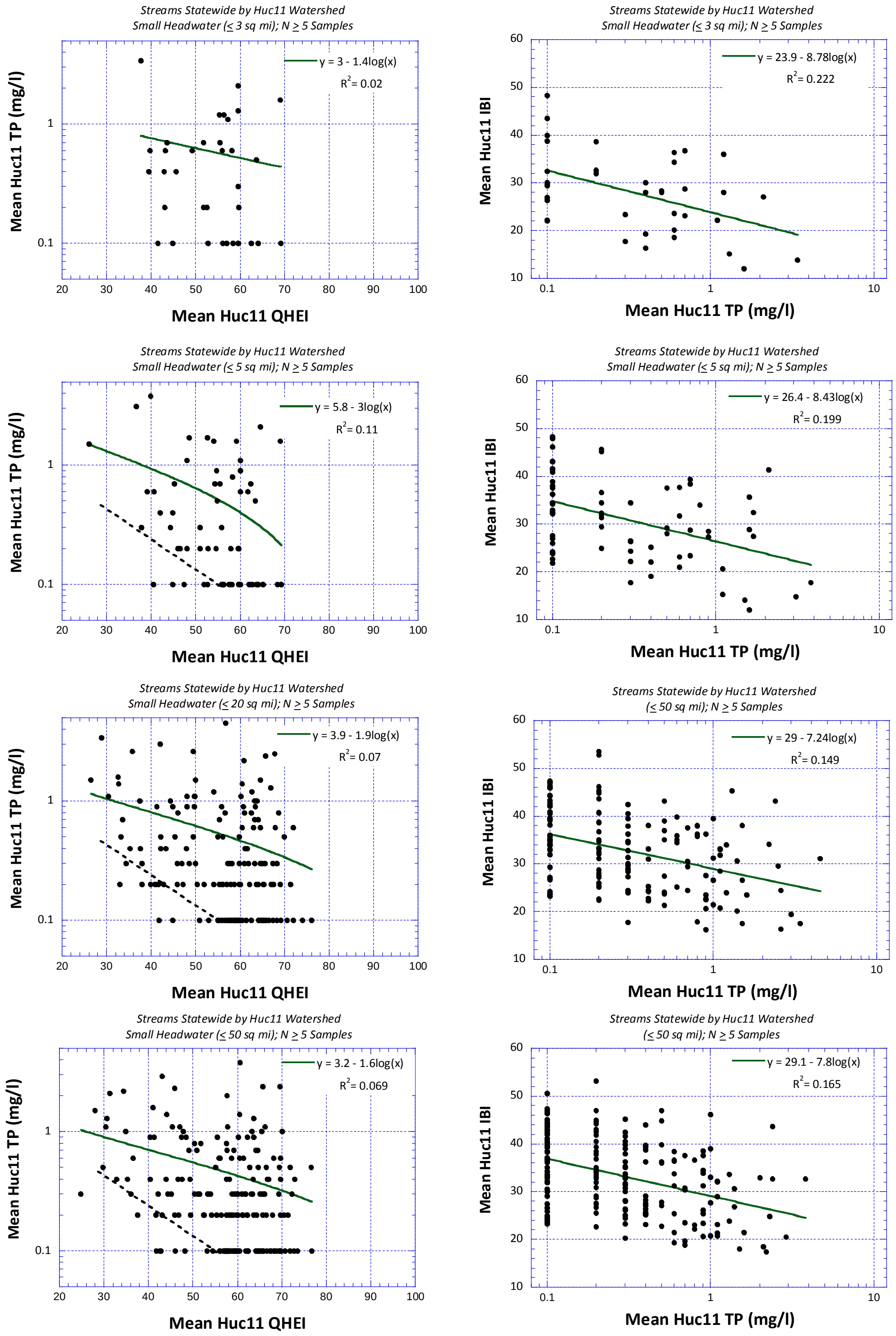


Figure 7. Plots of mean Huc11 QHEI scores vs. mean Huc11 TP (mg/l) values (left) and mean Huc11 TP (mg/l) vs mean Huc11 IBI (right) for streams of <3.0 sq. mi. (upper), <5.0 sq. mi., <20 sq. mi., and <50 sq. mi. (lower) for HELP and ECBP streams during 1981-2009. Dashed lines represent a floor threshold relationship drawn by eye.

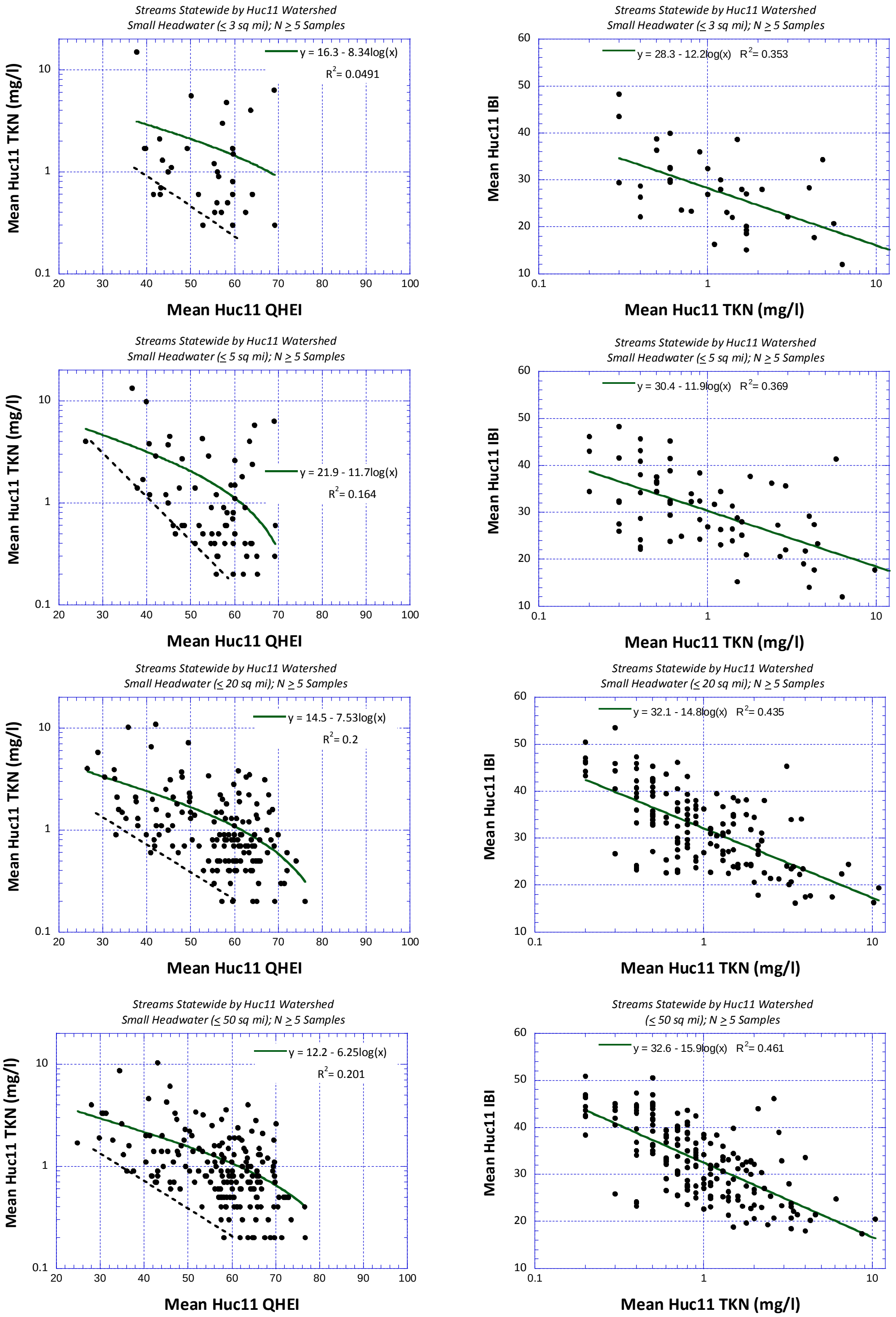


Figure 8. Plots of mean Huc11 QHEI scores vs. mean Huc11 TKN (mg/l) values (left) and mean HUC11 TKN (mg/l) vs mean Huc11 IBI (right) for streams of <3.0 sq. mi. (upper), <5.0 sq. mi., <20 sq. mi., and <50 sq. mi. (lower) for the HELP and ECBP during 1981-2009. Dashed line represents a floor threshold relationship drawn by eye.

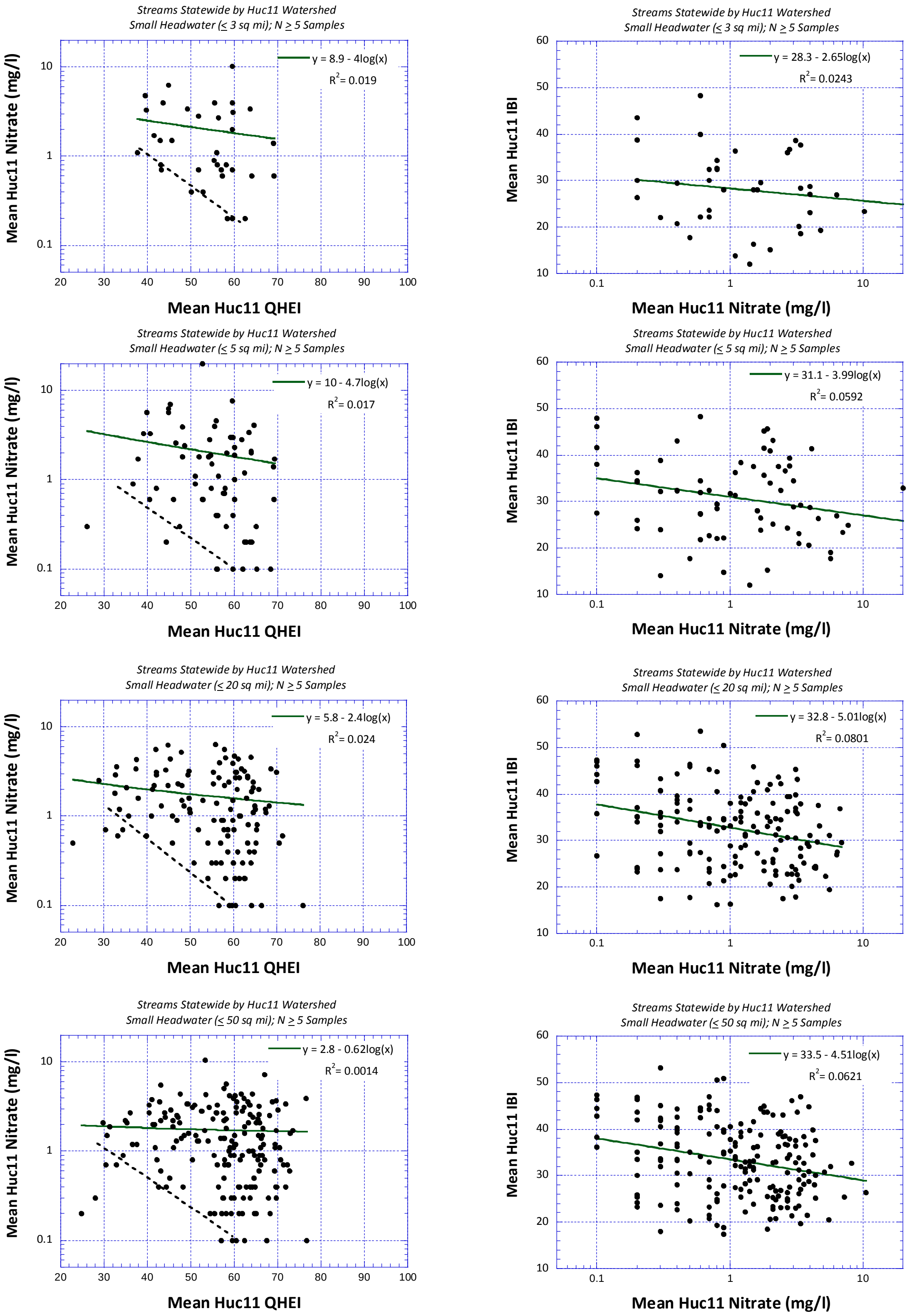
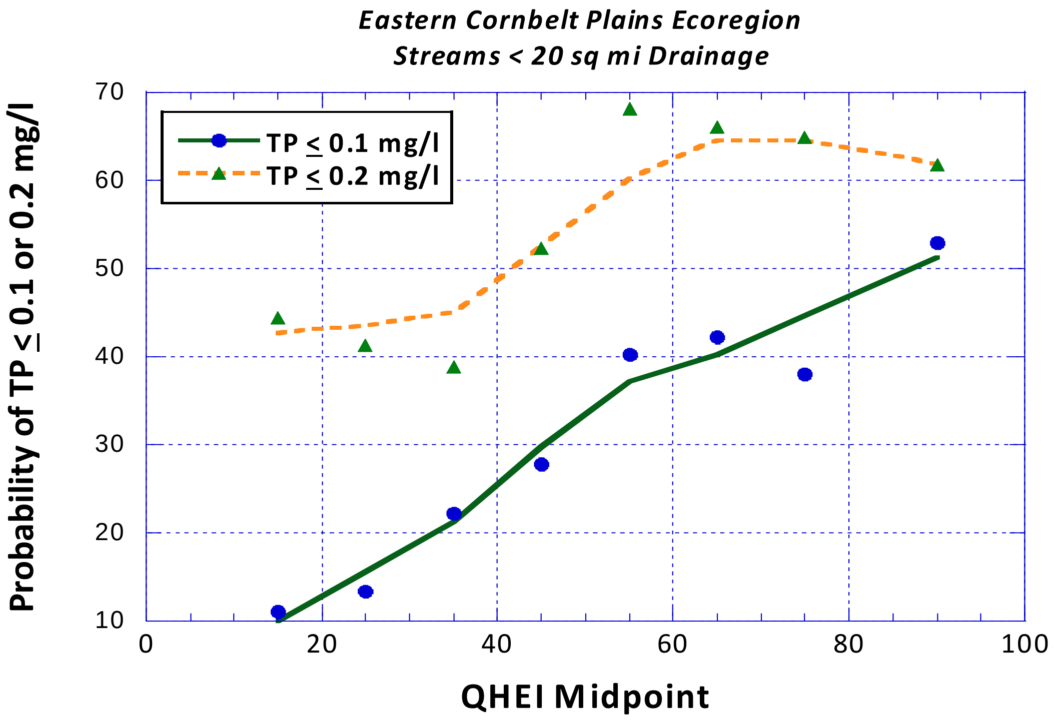


Figure 9. Plots of mean Huc11 QHEI scores vs. mean Huc11 NO_3 (mg/l) values (left) and mean HUC11 NO_3 (mg/l) vs mean Huc11 IBI (right) for streams of <3.0 sq. mi. (top), <5.0 sq. mi., <20 sq. mi., and <50 sq. mi. (lower) for the HELP and ECBP during 1981-2009. Dashed line represents a floor threshold relationship drawn by eye.



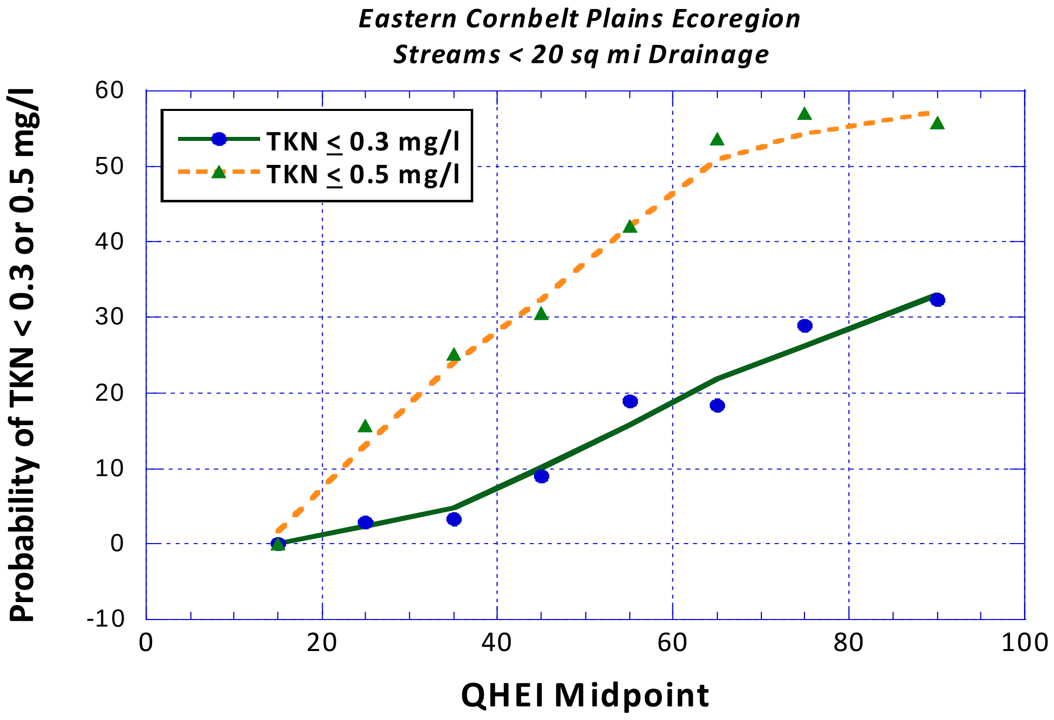


Figure 10. Plots of QHEI midpoints (20 bins of equal sample size) vs. the probability of TP values <0.1 (solid line) or <0.2 (dashed line) mg/l (upper) or the probability of having TKN values <0.3 (solid line) or <0.5 (dashed line) mg/l (lower).

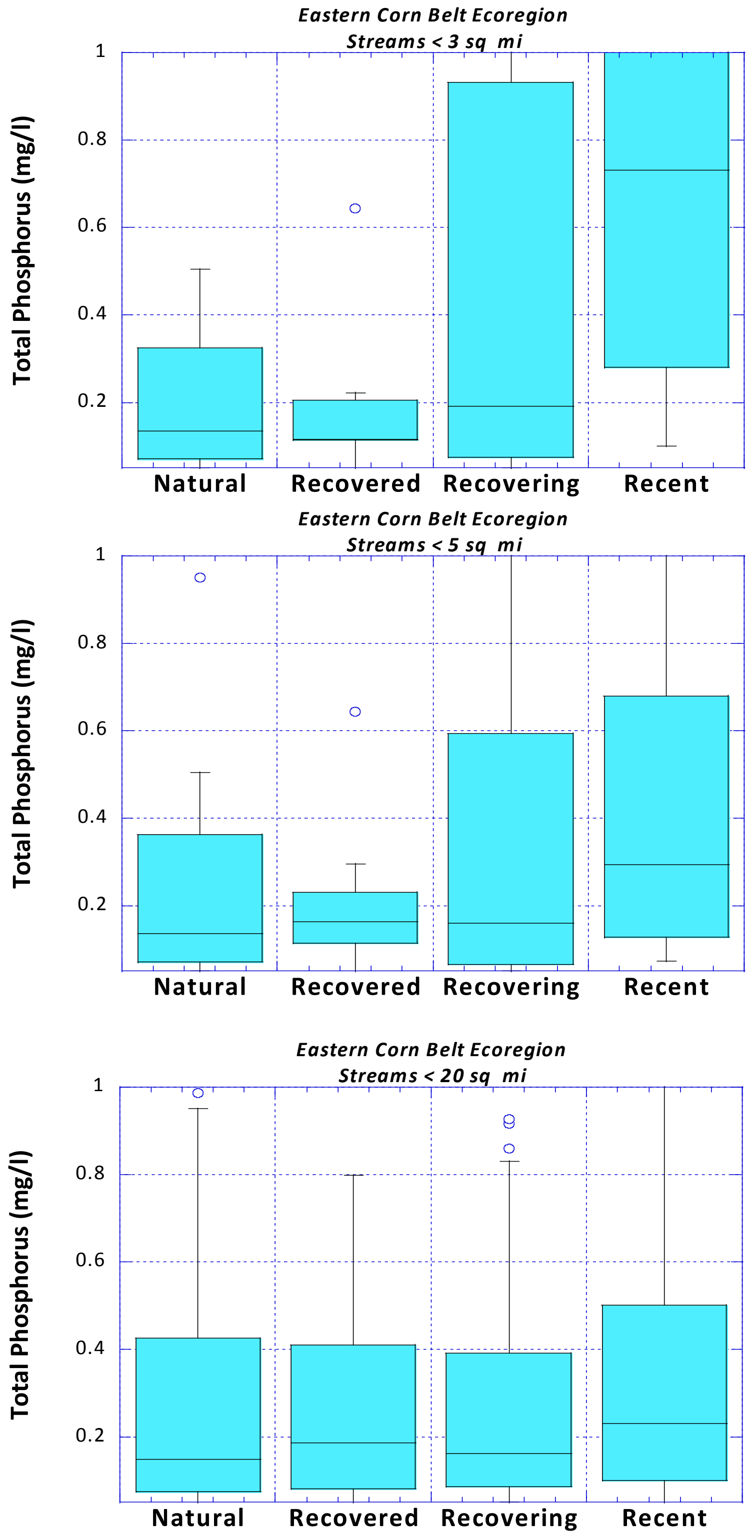


Figure 11. Box-and-whisker plot of total phosphorus (mg/l) vs. QHEI channel condition for headwater streams of <3.0 sq. mi. (upper), <5.0 sq. mi. (middle) and <20 sq. mi. (lower) based on site-specific data.

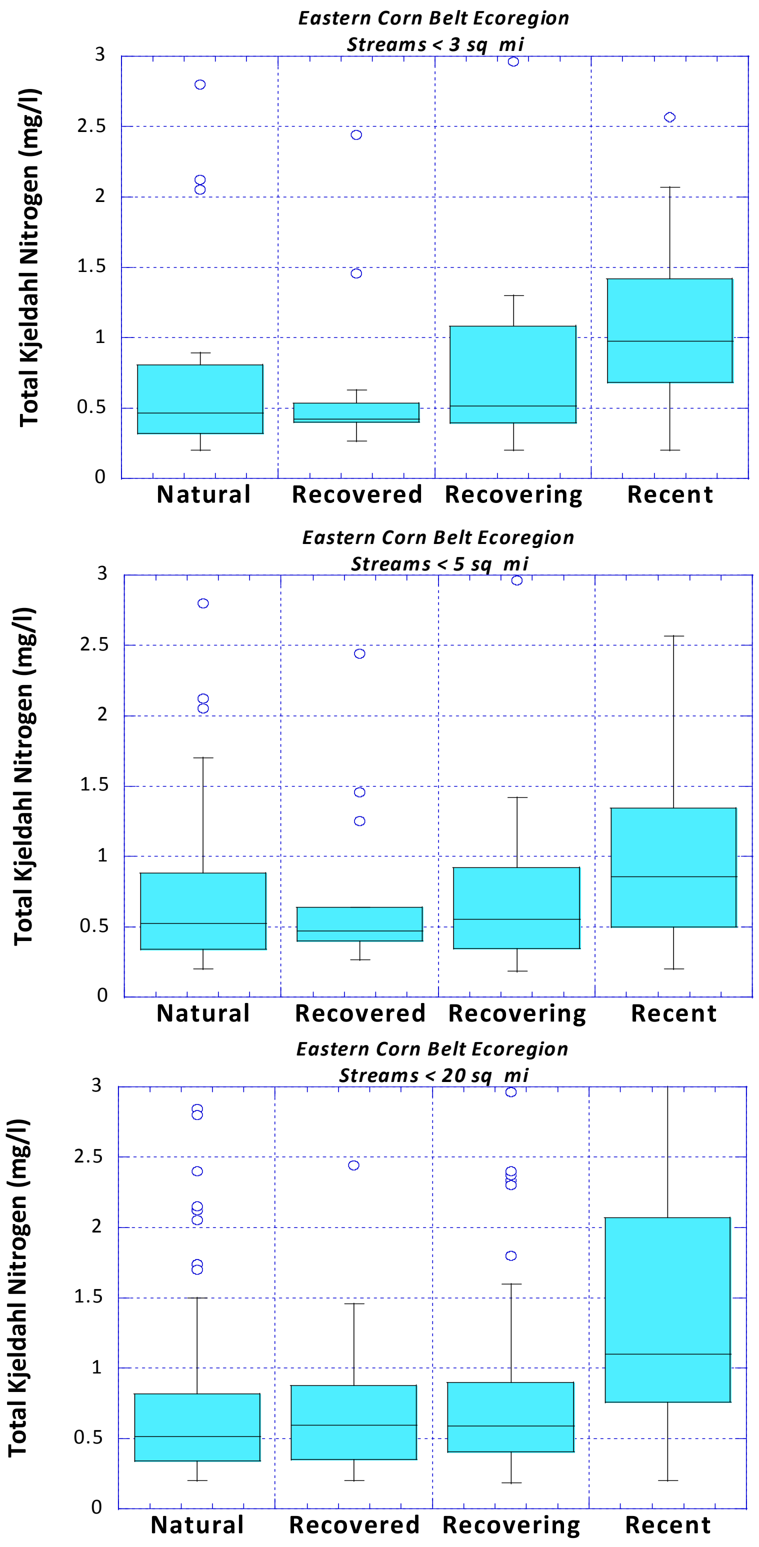


Figure 12. Box-and-whisker plot of TKN (mg/l) vs. QHEI channel condition for headwater streams of <3.0 sq. mi. (upper), <5.0 sq. mi. (middle), and <20 sq. mi. (lower) based on site-specific data.

value increases sharply with increasing QHEI scores (Figure 10). TKN by each of the four channel conditions of the QHEI channel metric (natural, recovered, recovering, and recent or no recovery) for headwater streams <3.0 sq. mi., <5.0 sq. mi. and <20 sq. mi. (Figure 12) showed a similar pattern to TP in small streams. This supports the existence of a strong link between channel condition and instream concentrations of TKN in the smallest headwater streams.

Total Nitrate (NO_3)

Nitrate showed similar results as TP and TKN at the Huc-11 watershed scale, but exhibited a weaker association with IBI (Figure 9). At the site-specific scale the associations were weakest even at the floor threshold and between categories of channel condition reflected in the QHEI channel metric (Figure 13). Some of this may be related to the use of grab samples to characterize nitrate concentrations which can "linger" following runoff events because they are mostly delivered though tile drainage systems. Thus at a given site and depending on the temporal association with runoff events, nitrates can remain elevated after an event has subsided. The Huc-11 associations are thus much more likely to "average-out" this temporal variation and the analyses at that scale illustrated a better floor relationship with QHEI (Figure 9). In natural forested headwater streams nitrate concentrations are typically very low and nitrate is efficiently transformed to N_2 and lost to the atmosphere via denitrification. Peterson et al. (2001) documented this process for a number of headwater streams across the U.S. and concluded that the higher benthic surface to water volume ratio of these small streams was fundamental to this finding. In the traditional trapezoid drainage ditches in Ohio this function is altered and nitrate concentrations are not only higher, but are exported more rapidly downstream (Richards et al. 2008). Experimental studies in small headwater streams show that natural streams are more efficient in removing nitrogen and that naturally restored channels have greater removal efficiencies than two-stage channels with the lowest removal efficiency associated with traditional trapezoidal channels (Zika 2008).

Summary of Habitat-Nutrient Associations

Given the strong linkages between instream habitat quality and nutrient cycling the physical characteristics of stream channels in small headwater streams should be an important consideration for generating realistic expectations for meeting nutrient targets and water quality criteria. Overland delivery of nutrients can overwhelm the nutrient assimilative capacity of any headwater stream regardless of the inherent assimilative capacity. However, it appears that based on existing research and the analyses herein achieving nutrient levels low enough to meet the Ohio nutrient targets and water quality criteria is precluded when headwater stream habitat is fair, poor, or very poor as measured by the QHEI. The inclusion of the traditional trapezoidal channel as the baseline management practice for the **DU** proposal is at odds with being able to attain and maintain the Ohio nutrient targets at the drainage pour points. This is further supported by studies that manipulated nitrogen levels (Zika 2008) as well as correlative studies of nutrient concentrations and loadings in ditches (Richards et al. 2008).

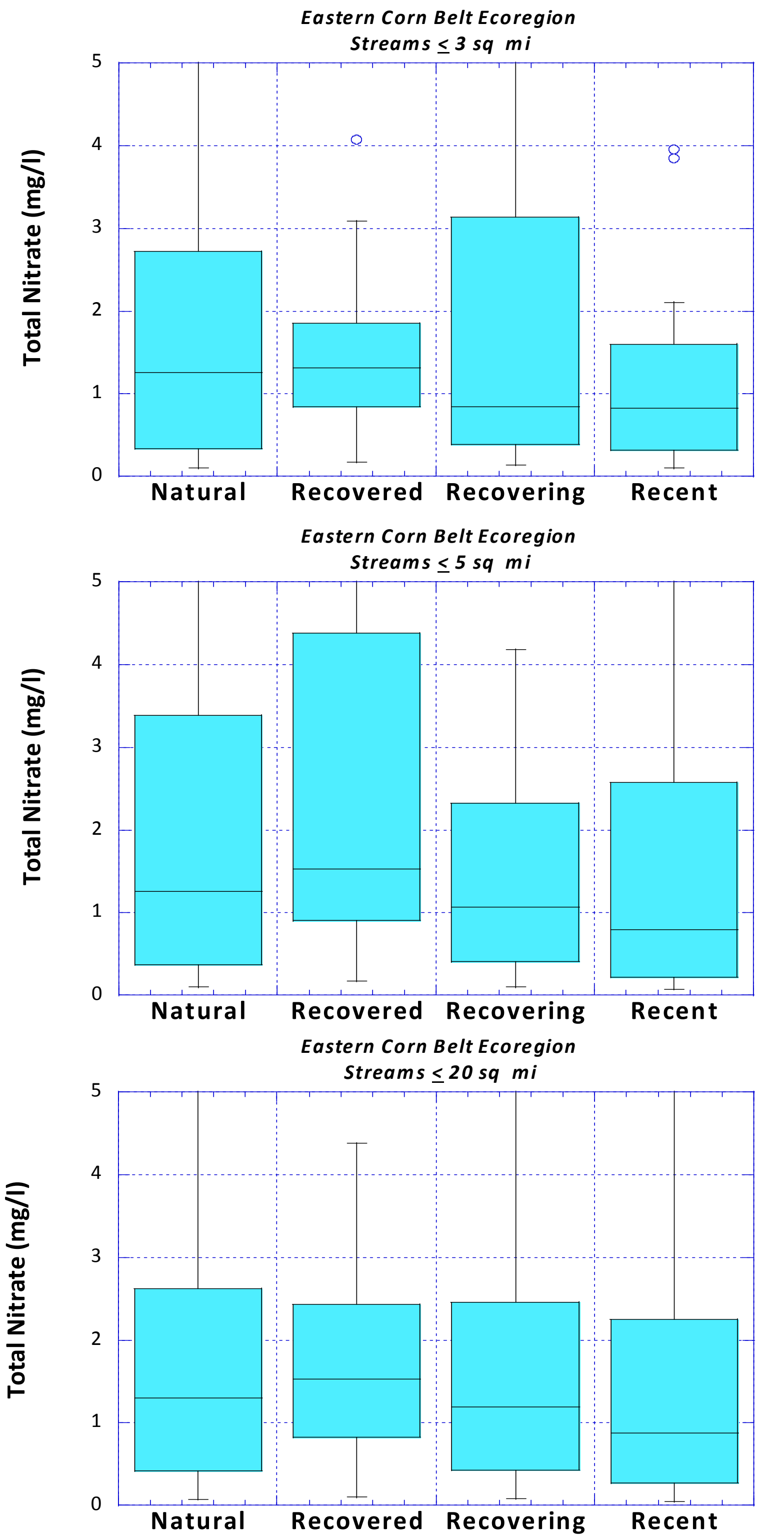


Figure 13. Box-and-whisker plot of total nitrate (mg/l) vs. QHEI channel condition for headwater streams of <3.0 sq. mi. (upper), <5.0 sq. mi. (middle), and <20 sq. mi. (lower) based on site-specific data.

III. Water Quality Criteria vs. Biocriteria in Small Headwater Streams

Biological assemblages are used as indicators of stream and river quality in every state of the U.S. It is their ability to integrate multiple stressors that makes them a more effective measure of quality than chemical or physical measures alone. As such biological criteria were codified in the Ohio WQS in 1990 as the principal arbiter of aquatic life use attainment and non-attainment. Ohio-based studies were among the first to show that biological measures *more effectively detected pollution than water chemistry alone* (Ohio EPA 1992; Rankin 2003b). Under the proposed **DUs** biological criteria would be eliminated from streams <3.125 sq. mi. with only chemical water quality criteria applying under a General Use framework. A consequence of a chemistry-only approach to stream assessment would be a significant under-reporting of impaired waters as intended by the CWA. However, because chemical exceedances can also occur when the biological criteria are met, the proposed **DUs** could result in an "over-reporting" in cases where chemical criteria are exceeded. The current Ohio WQS contain language that deals with "disagreements" between biocriteria-based and chemical criteria-based findings of attainment and non-attainment[7].

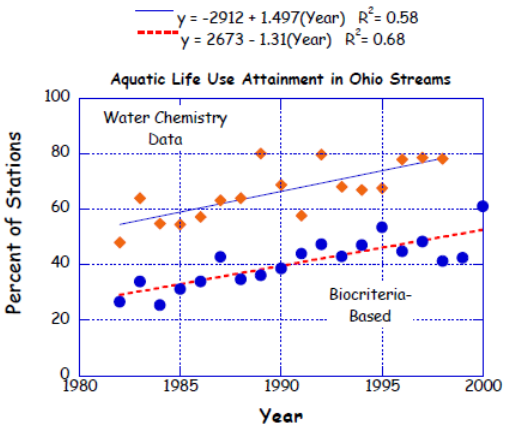


Figure 14. Percent of sites attaining aquatic life uses using water chemistry data alone (diamonds) vs. using biocriteria (dots) in Ohio during 1982-2000. (after Rankin 2003b).

Figure 14 shows the results of using water chemistry alone vs. biocriteria for detecting impairments over a nearly 20 year time frame. The regression lines in Figure 14 indicate that in year 2000 reporting, water chemistry data would have identified 18% of streams and rivers as impaired while biocriteria would have identified 47% as impaired, a difference of 29% percent. This represents impairments detected by bioassessment that were missed by water chemistry data and which could be due to stressors other than chemical pollutants, chemical stressors that were missed, or the effects of episodic stressors not represented in the chemical data.

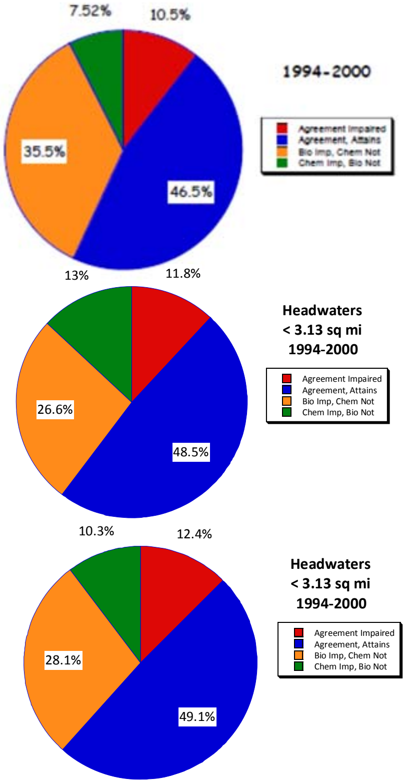


Figure 15. Pie charts of agreement or disagreement between biocriteria-based and water chemistry-based determinations of aquatic life use attainment. Upper pie chart is statewide (after Rankin 1983); middle and lower pie charts are based on same dataset restricted to streams <3.125 and 10 sq. mi., respectively.

In another comparison, focused on data from 1994–2000, 35.5% of sites during that time period were biologically

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[7] OAC 3745-1-07[A][6]

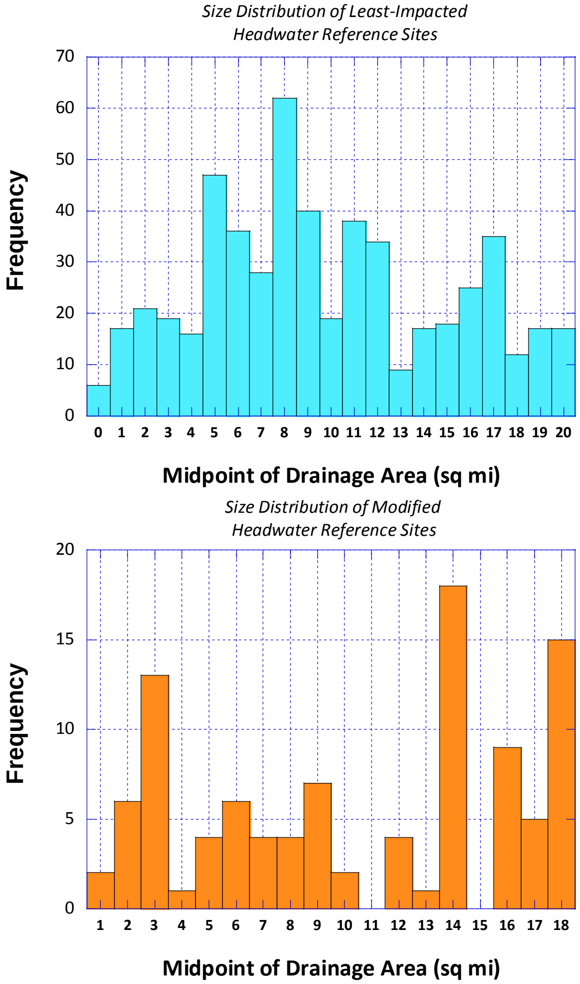
impaired with no associated indication of chemical impairment (Rankin 2003b; Figure 15, upper). The same analysis for the same time period focused on headwater streams ≤3.125 sq. mi. and ≤10 sq. mi. yielded similar results (Figure 15, middle and lower). While there were slightly fewer sites where the biological and chemical assessment agreed about attainment, there were *more sites with a chemical impairment* and no corresponding biocriteria impairment. Thus, eliminating the biocriteria from headwater streams will in some instances *increase* impaired waters listings.

A principal rationale for the proposed **DUs** is to ease 404/401 requirements for channel maintenance related to agricultural drainage by removing considerations related to meeting and maintaining the biocriteria-based aquatic life uses. An unanticipated result of the removal of the biocriteria may include scenarios where water chemistry-based assessment would lead to increased listings in headwater streams spurred by chemical exceedances alone. The mere avoidance of biocriteria in these cases will not only increase impairment listings, but will significantly reduce the accuracy of stressor identification which could mask the true causes of downstream water quality impairments and result in misguided management actions as a result. The role of biological assessment in detecting a wider array of stressors is the greater penalty to headwater stream assessment under the proposed **DUs**. It seems likely that any ambient monitoring of streams <3.125 sq. mi. and possibly <10 sq. mi. would cease to be a routine part of the Ohio EPA watershed monitoring program. This would most likely leave a vacuum that would be replaced by the assumed capabilities of trapezoidal and two-stage ditches to meet WQS and without these practices ever being validated with routine monitoring and assessment.

Another premise of the proposed **DUs** is that the current biocriteria have been inappropriately extended beyond their ". . . intended application to larger streams and rivers . . ." by applying them to smaller headwater streams. This assertion belies the facts as the Ohio IBI was not only calibrated to drainage areas of 1.0 sq. mi., they have been used for more than 30 years to designate headwater streams. This issue can easily become confused as there are some small streams >1.0 sq. mi. that cannot attain the WWH biocriteria due to ephemeral flows. However, the Ohio IBI for the headwater site type was purposely designed to detect this from a biological standpoint (i.e., by the inclusion of flow dependent metrics) knowing that physical predictors of fish assemblages *alone* are inadequate for this task. This is vetted as part of the Ohio UAA process, thus many headwater streams that fall under the proposed **DUs** have been already been designated as MWH or LRW. Furthermore, since the controlling characteristics (i.e., flow, channel integrity) in many headwater streams have been altered especially in the ECBP and HELP ecoregions, it becomes even more difficult to predict when WWH is attainable based on non-biological measures alone. Simply "deleting" a class of headwater streams from biologically based use potential determinations will certainly result in the mismanagement of those resources in addition to abrogating the U.S. EPA Exiting Use clause.

The Ohio IBI for the headwater site type (applies at <20 sq. mi.) was specifically derived and calibrated for headwater streams as small as 1.0 sq. mi. as evidenced by each Ohio ecoregion containing one or more reference sites of 1.0 sq. mi. Hence by definition of the derivation process itself the biocriteria ***do apply*** to these small headwater streams. This is illustrated by frequency histograms of least-impacted and modified reference sites (Figure 16) that were used to set the headwater site type biocriteria for the **WWH** and **MWH** uses. There are clearly numerous sites <10 sq. mi. and <3.125 sq. mi. that are as commonly distributed in the dataset as those in the upper range of drainage sizes (i.e., >10 sq. mi.). The IBI metrics were calibrated by the accepted methodology of deriving continuous curves along ceiling relationships of the species richness metrics.

The lack of sufficient flow and water volume in small headwater streams is frequently not a "natural" occurrence, but may be due to the legacy effect of watershed alterations such as conventional drainage practices and the associated lowering of groundwater tables and summer base flows. The effects of flow alteration by channel modifications are integrated into the measurement of biological responses to habitat changes that include changes to these base flow conditions. The current **MWH** and **LRW** use tiers reflect these alterations and their needs via the current UAA process.


Size Distribution of Least-Impacted Headwater Reference Sites

Size Distribution of Modified Headwater Reference Sites

Figure 16. Frequency distribution by drainage area of Ohio's least impacted natural (upper) and channel modified (lower) headwater sites reference sites. Data from Ohio EPA.

IV. Conclusions

A major premise of the proposed **DUs**, implied or otherwise, is that the mitigation standards described in the Ohio Drainage Manual will adequately compensate or over-compensate for the removal of the biocriteria as the arbiter of ALUSE attainment in headwater streams. Another stated goal of the proposed **DUs** is the protection of “downstream uses.” The extant information and analyses herein show a strong, primary relationship between the IBI (a measure of aquatic life performance) and habitat quality at the local, reach, and watershed scales (Figure 17).

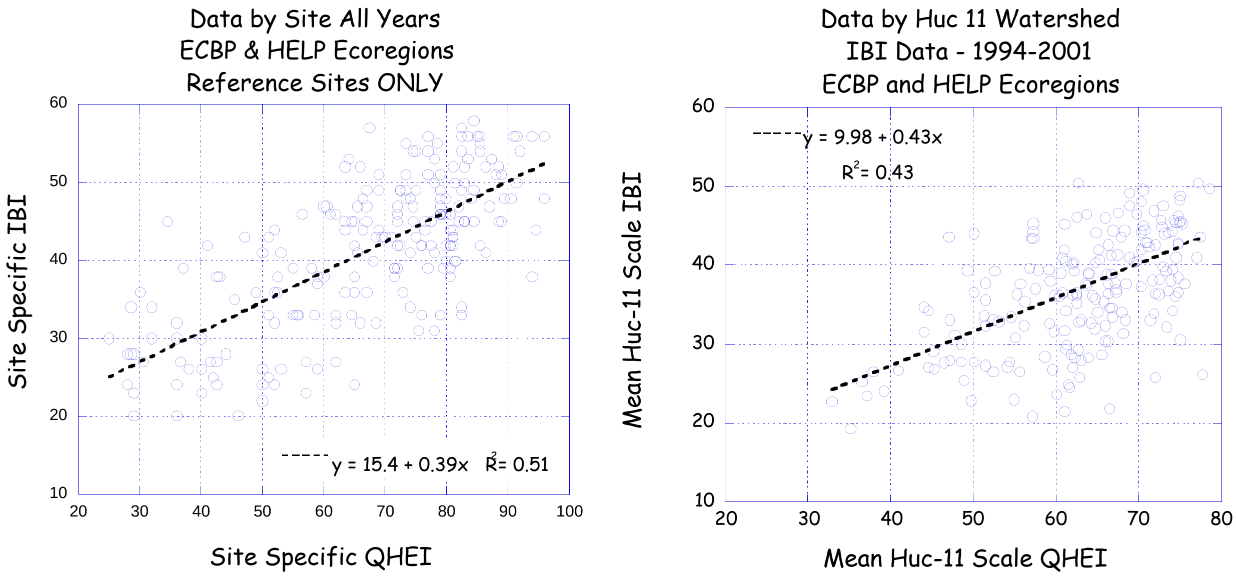


Figure 17. Plot of site-specific QHEI (left) and Huc-11 scale average QHEI (right) vs. IBI (site specific or average) for least impacted and modified reference sites in the ECBP and HELP ecoregions of Ohio. Data from Ohio EPA.

If the implementation of the **DUs** results in the loss of habitat quality in small streams that are considered **HC**, but which have recovered sufficient habitat features to either attain or potentially attain **WWH** (which also meets the provisions of the U.S. EPA Existing Use clause), then these premises of the **DU** proposal are not valid. Data from Ohio (Armitage et al. 2009) indicates that an accumulation of poor habitat attributes within a Huc-11 watershed results in the extirpation of sensitive fish species (Figure 18) and other aquatic assemblage attributes that drive IBI scores consistent with **WWH** (or better) status. The presumed acceptance of the trapezoidal channel as an acceptable mitigation practice would “lock in” poor biological performance in already altered watersheds and would also lead to “backsliding” in watersheds where small streams have naturally recovered from prior alterations (i.e., the threshold points in Figure 18). Thus a key problem with the proposed **DU** is its acceptance of traditional and unproven[8] two-stage channel designs in small streams where substantial natural recovery has already occurred, but where monitoring and an accompanying UAA have not yet “locked in” **WWH**. This

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[8] Unproven refers to a lack of studies showing the *consistent* attainment of the Ohio EPA biocriteria.

problem will only be exacerbated if Ohio EPA ceases to assess stream sizes that are included in the proposed **DUs**.

Rankin (1989) examined the ratio of poor QHEI attributes to good attributes in Ohio streams and found that sites with modified:good attribute ratios <2 are generally able to support **WWH** fish assemblages and ratios >2 are generally evidence of an increasingly habitat limited situation with regard to attaining **WWH**. The analyses herein suggest that the statewide application of the proposed **DUs** would subject substantial numbers of streams that currently meet **WWH** or better aquatic life uses to "traditional" trapezoidal ditch or unproven two-stage ditch designs. This will predictably result in the loss of biological quality and the extirpation of sensitive fish species. It is difficult to conceive how the loss of species in streams <3.125 sq. mi. could protect or at least be neutral to the biological assemblages in downstream reaches. The analyses in this report suggest that it cannot do either, particularly if the **DU** acceptable channel designs are widely applied. Even where there is the potential for implementation of two-stage channels or over-wide ditch designs there is not yet sufficient and credible evidence that these practices will protect aquatic life consistent with **WWH**. The analysis of spatial patterns in **WWH** or better potential for Ohio headwater streams indicates that under-protecting biological assemblages is a particular vulnerability in the IP, WAP, and in parts of the EOLP and ECBP ecoregions. More predictive analyses could be performed that would more precisely identify areas that would most likely be under-protected. Given the link between habitat and biological condition and the gross error associated with the **DU** proposal assuming that streams <3.125 sq. mi. are consistently of limited quality, it seems the current approach of resolving drainage related habitat modifications via the UAA process is not only the preferred technical approach, but also assures consistency with U.S. EPA water quality regulations. The analyses herein might be used to reveal where UAAs could be streamlined on a subwatershed as opposed to a stream-specific scale even though that practice has been used in Ohio UAAs in the past.

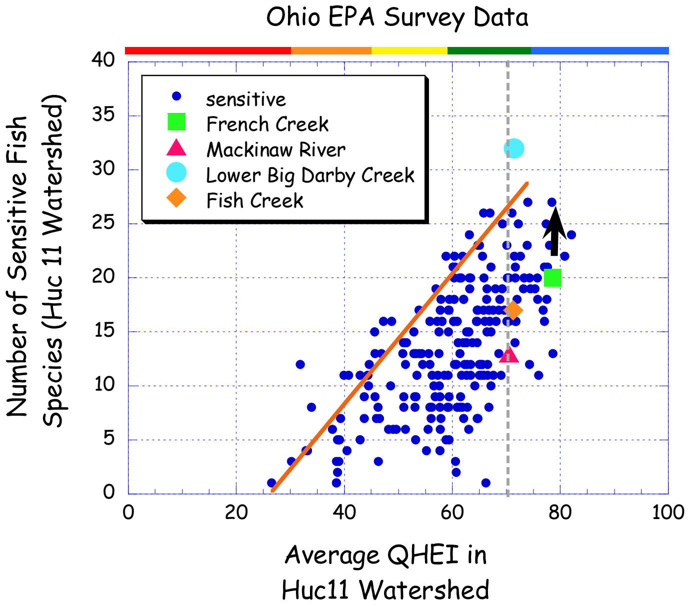

Figure 18. Plot of mean QHEI in Huc-11 watersheds and the cumulative number of sensitive fish species in each Huc-11 watershed. The orange line is a threshold "ceiling" drawn by eye.

Evidence for Two-Stage Ditches Adequately Protecting Aquatic Life

No evidence was found in the literature that was examined about the ability of two-stage ditches to support aquatic life assemblages commensurate with the Ohio **WWH** aquatic life use. This may largely be due to the fact that such projects were just beginning to be conducted and monitored in a fashion that would be amenable to gaining useful results (Huang et al. 2009). We also perused the Ohio EPA

319 publications related to such projects and found that these were focused on natural channel design projects. Clearly, in order to show that two-stage ditches can deliver on the presumptions of the proposed **DUs**, biological sampling and analyses consistent with Ohio EPA methods and the Ohio Credible Data Law[9] would be needed in order to reach a valid conclusion.

Studies about the capacity of two-stage ditches to assimilate nutrients were available. A preliminary study by Zika (2008) documented the N assimilation differences between natural channels, naturally restored channels, over-wide ditches, two-stage ditches, and trapezoidal ditches. It found assimilative capacity to be highest in the natural channels and lowest in the trapezoidal and two-stage channels. Because of these findings it is not possible to agree that the proposed **DU** mitigation practices being focused on traditional trapezoidal channels, two-stage ditches, or over-wide ditches will be protective of downstream uses as they are defined by the Ohio WQS.

Development of an Approach to Stream Mitigation that Enhances Drainage, Agricultural Economies, and Biological Condition

A major shortcoming of the processes either referenced or implied by the proposed **DUs** and as detailed in the draft Ohio Drainage Manual is the lack of a sustainable and long-term approach to stream management. The short-term needs of agricultural drainage within the constraints of "traditional" row crop agriculture seemingly omit more long-term, "outside-the-box" approaches that could benefit both agricultural and ecological systems in the Midwestern U.S. Recent reviews on stream drainage practices and environmentally beneficial management practices, while useful, may not expand sufficiently outside of the current practices to consider feasible options to maximize ecological and economic returns (Needleman et al. 2007, Strock et al. 2010). More sustainable management options are needed, even if some of the most sustainable options are presently outside of current convention related to agricultural drainage management. The issues that prompted the proposed **DU**s are not new and have had a repetitive cycle of controversy over the past 30+ years due primarily to a lack of innovation in this area. New approaches are needed to get past the extant and long standing conflicts between agricultural drainage and CWA goals.

A predictable consequence of the proposed **DUs** and the accompanying Ohio Drainage Manual is the further institutionalization of conventional drainage designs and the application of those designs to streams that have either recovered substantial good habitat attributes, some of which were never actually "ditched" to the extent assumed by the proposed **DUs**, or which are currently attaining a CWA goal designated aquatic life use. The current framework of tiered aquatic life uses and the attendant UAA process is a demonstrated and workable framework for stream management applicable to agricultural drainage. In an Ohio DNR survey of landowners about reasons that a petitioned ditch was rejected the smallest category of response was "environmental objections or concerns" (Page 6, Ohio DNR 2008). More frequently the reason that most projects were rejected had to do with the cost of the project itself. Thus it is suggested that the proposed **DU**s provide a framework for water conveyance that largely abrogates CWA goals in jurisdictional streams. It would be environmentally more

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[9] Ohio Revised Code 6111.5 and OAC 3745-4.

meaningful if more incentives were in place to move best management practices away from the traditional channelization designs towards more sustainable designs that also meet WQS. However, it is also recognized that there will be places where the traditional designs are the only option and this is already recognized by the designation of some Ohio streams as **MWH** and **LRW** for channel maintenance reasons.

Table 9 is a conceptual model of the quality and types of ecological functions of headwater streams that would be delivered by various channel design options and as compared to an unaltered (or fully recovered) stream. Some of the designs and the resulting quality of functions have not been sufficiently tested via research and with rigorous enough monitoring data, hence it serves as a hypothetical characterization based on our current understanding based on this analysis, reviews of the literature, and experience with monitoring streams subject to these types of practices. Part of the difficulty with this approach is the lack of robust datasets to test some of these designs (e.g., two-stage channels, over-wide channels, and biofuel benches). However, the results of assessing traditional trapezoidal channels are well known in that it almost always results in the impairment of the **WWH** use in headwater streams. The habitat mechanics as revealed by analyses of QHEI attributes provides a more predictable set of tools for evaluating the other ditch designs. Using that knowledge to predict the outcomes of less tested or untested designs is not all that great of a leap, particularly when some of those designs produce many of the same characteristics as the trapezoidal design. It would also be more effective to consider the costs and economic benefits related to each practice. The proposed **DUs** would seem to lock in traditional drainage practices with their already known lack of ecological functions without considering the long-term benefits of the more innovative and perhaps more sustainable practices such as natural channel designs.

Table 9. Hypothetical level of general ecosystem service functions provided by various channel design options.

Design Practice	**Nutrient Processing**	**Sediment Assimilation**	**Energy Dynamics**	**Hydrology**	**Climate Change**	**Biodiversity**
Traditional Trapezoidal	🟥	🟥	🟥	🟥	🟥	🟥
Two-stage Channel	🟧	🟧	🟧	🟥	🟥	🟥
One-Sided Channelization	🟨	🟨	🟨	🟧	🟥	🟧
Overwide Channel	🟨	🟩	🟧	🟧	🟥	🟧
Natural Channel Design	🟩	🟩	🟨	🟧	🟨	🟩
Unaltered Stream (unaltered or fully recovered)	🟦	🟦	🟦	🟩	🟩	🟦

Red – Very Poor; Orange – Poor, Yellow – Fair, Green – Good; Blue - Excellent

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Appendix 1. Draft Drainage Use Designation Language

(G) Drainage use designations.

[Comment: The terms ditch maintenance program and historically channelized watercourse are defined in rule 3745-1-02 of the Administrative Code.]

(1) Upland drainage.
  (a) These are water bodies constructed in the upper elevations of watersheds to drain relatively flat topography of excess water during wet periods.
  (b) The upland drainage use designation shall apply to all water body segments that:
    (i) Are historically channelized watercourses;
    (ii) Drain less than 3.1 square miles; and
    (iii) Have average gradients no greater than 0.6 per cent at watersheds up to one thousand acres, no greater than 0.4 per cent at watersheds up to fifteen hundred acres and no greater than 0.3 per cent at watersheds up to two thousand acres.

(2) Water conveyance.
  (a) These are water bodies constructed or modified from naturally occurring stream channels to convey excess water during flood events and to drain the landscapes of excess water during wet periods.
  (b) The water conveyance use designation shall apply to all water body segments that:
    (i) Are historically channelized watercourses;
    (ii) Drain 3.1 square miles or more;
    (iii) Are under a ditch maintenance program; and
    (iv) Are designated in rules 3745-1-08 to 3745-1-30 of the Administrative Code for one of the following subcategories of aquatic life use: warmwater habitat, modified warmwater habitat, or limited resource water.

(3) The director upon considering site-specific information supplied by a government entity responsible for drainage improvements may waive the gradient and drainage area restrictions for the drainage uses specified in paragraphs (G)(1) and (G)(2) of this rule.

(4) There are no chemical, bacteria or biological criteria designed for the drainage use designations.
[Comment: The criteria in rule 3745-1-04 of the Administrative Code, applicable to all waters, and the criteria associated with any other assigned beneficial use designations apply to these water bodies.]

(5) All waters assigned a drainage use designation and meeting the conditions of division (C) of section 6111.12 of the Revised Code shall be subject to an abbreviated antidegradation review under rule 3745-1-05 of the Administrative Code.

Definition of Historically Modified:

(48) "Historically channelized watercourse" means the portion of a watercourse, exclusive of adjacent wetlands, on which drainage improvements were constructed pursuant to Chapter 1515., 6131., or 6133. of the Revised Code, or were constructed under a similar state law that preceded any of those chapters. A drainage improvement is defined in divisions (C)(2) to (C)(4) of section 6131.01 of the Revised Code. If historical records cannot be located, then visual observations of side cast spoil banks in an upland landscape with supporting land surface elevation surveys may suffice as evidence that the watercourse was historically channelized.

Appendix 2. The QHEI as an Indicator of Limited Habitat in Small Headwater Streams

Ohio EPA uses biological assemblage responses as the primary arbiter of aquatic life use attainability because they are a direct measure of an aquatic life use and integrate the effects of multiple stressors that can impair and aquatic life use. Most frequently limitations that result in lower than CWA uses, for example, Modified Warmwater Habitat (**MWH**) or Limited Resource Water (**LRW**), are due to habitat and/or flow limitations. Some of these limitations would be germane to the identification of candidates as **HC** streams for the **DUs**. These altered habitat and flow attributes are not uniformly distributed across Ohio. Further analyses of key habitat attributes could prove useful in deciding where to apply the **DU** concept in a UAA and where the risk of the misclassification of waters as a **DU** is unacceptable and where a **WWH** or better potential exists.

Table A-1 presents QHEI current (i.e., velocity of flow) attribute data for small headwater stream subcategories (≤1.0 sq. mi., >1-3.125 sq. mi., >3.125-10 sq. mi.) by gradient category (all gradients or low only <15.85 ft./mi.) and by Level III ecoregion. The HELP ecoregion shows the most widespread differences in current velocity characteristics. For the smallest stream size category (≤1.0 sq. mi.) the HELP ecoregion has a higher proportion of intermit streams than any other ecoregion. In addition non-HELP ecoregions have a much larger proportion of ≤1.0 sq. mi. streams having moderate current velocity which indicates that they are more likely to have permanent flows.

In Table A-2 sites are organized by Level IV US. EPA subregions. Yellow shaded cells have a low percentage of sites with QHEI moderate current velocity (<40%) or high flow intermittency. These subregions would likely have more drainage altered streams with limited habitat. Conversely subregions with blue shaded cells have a high percentage of sites with QHEI moderate (>70%) or fast current flow (>20%). These in turn are more likely to have permanent flow and better habitat on average and a higher potential to support at least the **WWH** or better use designation. The Mad River Interlobate subregion (55c) of the ECBP for example has good current velocity at all stream sizes and stream gradients. Other subregions with good current velocity include the Erie Georges (61c) and the Darby Plains (55e). Such areas should have few needs for consideration as **MWH** or **LRW** for **HC** streams. The spatial patterns by Level IV ecoregion in terms of the percentage of sites with moderate current velocity for sites 1.0-3.125 sq. mi. are illustrated in Figure A-1 for **HC** sites (all gradients). Sites with ≤20% of sites with moderate velocity are depicted in orange, sites with >20-40% of flows as moderate are in yellow, sites with >40-70% are depicted in green and sites with greater than >70% are depicted as dark blue. Clearly northwest Ohio has more flow limited

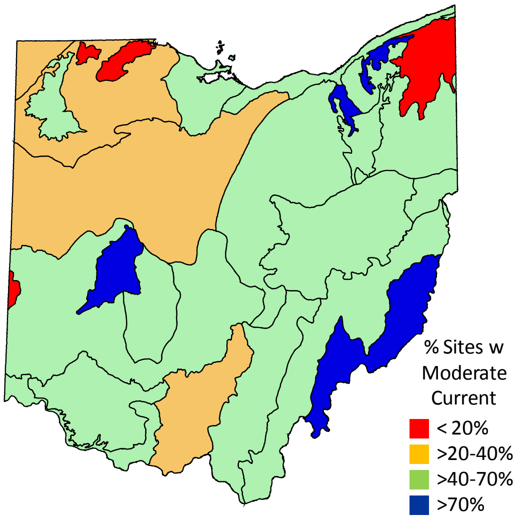

*Figure A-1. Map of Level IV Ecoregions in Ohio color coded by percentage ranges of 1.0-3.125 sq. mi. sites with QHEI moderate current velocity. These sites represent all gradients and those that are candidates as **HC** based on QHEI channel condition.*

streams which is a legacy of the historical loss of wetlands and altered stream channels. Mad River and other watersheds are naturally more water-rich, have not been as affected by stream alterations, and are thus more likely to have moderate and high current velocity as revealed by the QHEI.

Table A-1. QHEI flow attribute data (percent occurrence) by stream size, stream gradient category (all or <15.85 sq. mi.) and ecoregion for ***HC*** *small streams in Ohio. Candidates as a* ***HC*** *streams are those identified by the QHEI channel condition metric as having any other than a natural channel (recovered, recovering, or recent/no recovery).*

Eco-region	Stream Size	Gradient	No. of Sites	Current Types				
				Inter-mittent	Inter-stitial	Slow	Moder-ate	Fast
HELP	≤1.0 mi.^{2}	All Gradients	14	21.4	0.0	57.1	14.3	0.0
EOLP			29	3.5	0.0	93.1	58.6	0.0
WAP			46	10.9	15.2	80.4	54.3	10.9
ECBP			104	3.8	2.9	80.8	52.9	6.7
HELP		Low Gradient < 15.85 ft./mi.	11	18.2	0.0	63.6	9.1	0.0
EOLP			13	0.0	0.0	84.6	46.2	0.0
ECBP			22	0.0	4.6	77.3	50.0	4.6
HELP	>1.0-3.13 mi.^{2}	All Gradients	41	7.3	2.4	90.2	14.6	2.4
IP			20	0.0	15.0	100.0	65.0	15.0
EOLP			74	0.0	4.1	90.5	63.5	16.2
WAP			130	7.7	9.2	85.4	61.5	16.9
ECBP			229	7.4	5.2	84.3	49.3	7.0
HELP		Low Gradient < 15.85 ft./mi.	34	8.8	2.9	88.2	14.7	0.0
EOLP			34	0.0	5.9	88.2	52.9	5.9
WAP			18	0.0	5.6	88.9	50.0	11.1
ECBP			121	9.9	3.3	81.8	33.9	3.3
HELP	>3.13-10 mi.^{2}	All Gradients	162	2.5	1.9	90.7	32.1	1.9
IP			71	1.4	23.9	94.4	59.2	26.8
EOLP			298	1.7	2.3	91.9	69.8	24.5
WAP			226	3.5	3.5	89.8	63.3	17.7
ECBP			602	5.8	4.7	85.1	54.8	13.1
HELP		Low Gradient < 15.85 ft./mi.	158	1.9	1.9	90.5	32.3	1.9
IP			25	0.0	12.0	100.0	64.0	40.0
EOLP			183	1.6	1.1	91.8	65.0	19.7
WAP			102	2.9	2.0	93.1	55.9	12.7
ECBP			455	7.5	4.0	83.5	49.9	11.2

Table A-2. QHEI flow attribute data (percent occurrence) by stream size, stream gradient category (all or less than 15.85 sq. mi.) and Level IV ecoregion for historical channelized candidate small streams in Ohio. Candidates as a ***HC*** *streams are those identified by the QHEI channel condition metric as having any other than a natural channel (recovered, recovering, or recent/no recovery). Yellow shaded cells have low percentage of sites with moderate current present (< 40%) or high intermittency; blue shaded cells have a high percentage of sites with moderate (> 70%) or fast current flow (> 20%).*

Eco-Region No.	**Level 4 Ecoregion Name**	**Stream Size**	**Grad-ient**	**Current Types**					
				No. Sites	**Inter-mittent**	**Inter-stitial**	**Slow**	**Moder-ate**	**Fast**
55a	Clayey High Lime Till Plains	<u>≤</u>1.0 sq. mi.	All Gradients	29	0.0	3.5	79.3	24.1	3.5
55b	Loamy High Lime Till Plains			61	3.3	3.3	80.3	57.4	4.9
55c	Mad River Interlobate Area			9	0.0	0.0	77.8	100.0	11.1
57a	Maumee Lake Plain			6	33.3	0.0	50.0	0.0	0.0
61c	Low Lime Drift Plain			17	0.0	0.0	94.1	64.7	0.0
70b	Monongahela Transition Zone			13	0.0	7.7	84.6	61.5	7.7
70d	Knobs-Lower Scioto Dissected Plateau			6	0.0	16.7	100.0	50.0	0.0
70e	Unglaciated Upper Muskingum Basin			8	12.5	0.0	87.5	50.0	12.5
70f	Ohio/Kentucky Carboniferous Plateau			9	33.3	55.6	55.6	44.4	0.0
55a	Clayey High Lime Till Plains		Low Gradient < 15.85 ft/mi	13	0.0	0.0	69.2	30.8	0.0
55b	Loamy High Lime Till Plains			6	0.0	16.7	100.0	33.3	0.0
55c	Mad River Interlobate Area			6	0.0	0.0	66.7	100.0	16.7
57a	Maumee Lake Plain			6	33.3	0.0	50.0	0.0	0.0
55a	Clayey High Lime Till Plains	1.0-3.13 sq. mi.	All Gradients	99	12.1	3.0	84.8	36.4	3.0
55b	Loamy High Lime Till Plains			103	4.8	5.8	84.5	61.2	8.7
55c	Mad River Interlobate Area			10	0.0	10.0	100.0	80.0	40.0
55d	Pre-Wisconsinan Drift Plains			14	0.0	7.1	100.0	64.3	7.1
55e	Darby Plains			8	0.0	0.0	100.0	62.5	12.5
57a	Maumee Lake Plain			18	5.6	5.6	72.2	27.8	5.6
57b	Oak Openings			15	0.0	0.0	100.0	6.7	0.0
61c	Low Lime Drift Plain			39	0.0	2.6	87.2	66.7	18.0
61d	Erie Gorges			11	0.0	0.0	100.0	81.8	36.4
61e	Summit Interlobate Area			14	0.0	7.1	85.7	42.9	0.0
70b	Monongahela Transition Zone			25	8.0	0.0	80.0	56.0	20.0
70c	Pittsburgh Low Plateau			10	0.0	10.0	80.0	70.0	10.0
70d	Knobs-Lower Scioto Dissected Plateau			15	26.7	6.7	93.3	40.0	6.7
70e	Unglaciated Upper Muskingum Basin			19	0.0	5.3	94.7	63.2	26.3

Table A-2. QHEI flow attribute data (percent occurrence) by stream size, stream gradient category (all or less than 15.85 sq. mi.) and Level IV ecoregion for historical channelized candidate small streams in Ohio. Candidates as a ***HC*** *streams are those identified by the QHEI channel condition metric as having any other than a natural channel (recovered, recovering, or recent/no recovery). Yellow shaded cells have low percentage of sites with moderate current present (< 40%) or high intermittency; blue shaded cells have a high percentage of sites with moderate (> 70%) or fast current flow (> 20%).*

Eco-Region No.	Level 4 Ecoregion Name	Stream Size	Grad-ient	Current Types					
				No. Sites	Inter-mittent	Inter-stitial	Slow	Moder-ate	Fast
70f	Ohio/Kentucky Carboniferous Plateau			46	6.5	13.0	82.6	65.2	6.5
55a	Clayey High Lime Till Plains		Low Gradient	77	13.0	1.3	83.1	31.2	1.3
55b	Loamy High Lime Till Plains			29	6.9	0.0	86.2	44.8	6.9
57a	Maumee Lake Plain			18	5.6	5.6	72.2	27.8	5.6
57b	Oak Openings			10	0.0	0.0	100.0	10.0	0.0
61c	Low Lime Drift Plain			18	0.0	5.6	83.3	50.0	5.6
61e	Summit Interlobate Area			8	0.0	0.0	87.5	37.5	0.0
70f	Ohio/Kentucky Carboniferous Plateau			10	0.0	20.0	90.0	40.0	10.0
55a	Clayey High Lime Till Plains	3.13 sq. mi.-10	All Gradients	285	8.8	4.6	84.6	34.7	6.3
55b	Loamy High Lime Till Plains			240	3.3	5.4	87.5	69.2	19.2
55c	Mad River Interlobate Area			48	2.1	0.0	70.8	83.3	41.7
55d	Pre-Wisconsinan Drift Plains			42	0.0	26.2	92.9	59.5	19.0
55e	Darby Plains			43	0.0	2.3	100.0	76.7	16.3
57a	Maumee Lake Plain			76	0.0	2.6	92.1	35.5	1.3
57b	Oak Openings			16	0.0	0.0	93.8	37.5	0.0
57c	Paulding Plains			14	14.3	7.1	78.6	35.7	0.0
57d	Marblehead Drift/Limestone Plain			19	0.0	0.0	89.5	42.1	0.0
61b	Mosquito Cr/Pymatuning Lowlands			11	0.0	18.2	90.9	45.5	9.1
61c	Low Lime Drift Plain			160	3.1	1.9	91.9	64.4	18.7
61d	Erie Gorges			8	0.0	0.0	100.0	100.0	62.5
61e	Summit Interlobate Area			55	0.0	0.0	89.1	70.9	29.1
70a	Permian Hills			7	0.0	0.0	100.0	85.7	28.6
70b	Monongahela Transition Zone			34	0.0	2.9	94.1	73.5	38.2
70c	Pittsburgh Low Plateau			7	14.3	0.0	71.4	71.4	14.3
70d	Knobs-Lower Scioto Dissected Plateau			34	11.8	5.9	85.3	50.0	8.8
70e	Unglaciated Upper Muskingum Basin			48	0.0	0.0	91.7	66.7	16.7
70f	Ohio/Kentucky Carboniferous Plateau			72	4.2	2.8	86.1	62.5	11.1
71d	Outer Bluegrass			12	0.0	33.3	100.0	66.7	8.3

Table A-2. QHEI flow attribute data (percent occurrence) by stream size, stream gradient category (all or less than 15.85 sq. mi.) and Level IV ecoregion for historical channelized candidate small streams in Ohio. Candidates as a ***HC*** *streams are those identified by the QHEI channel condition metric as having any other than a natural channel (recovered, recovering, or recent/no recovery). Yellow shaded cells have low percentage of sites with moderate current present (< 40%) or high intermittency; blue shaded cells have a high percentage of sites with moderate (> 70%) or fast current flow (> 20%).*

Eco-Region No.	**Level 4 Ecoregion Name**	**Stream Size**	**Grad-ient**	**Current Types**					
				No. Sites	**Inter-mittent**	**Inter-stitial**	**Slow**	**Moder-ate**	**Fast**
83a	Erie/Ontario Lake Plain			9	0.0	0.0	100.0	66.7	44.4
55a	Clayey High Lime Till Plains		Low Gradient	253	9.5	4.7	83.4	31.6	5.1
55b	Loamy High Lime Till Plains		Low Gradient	162	4.9	3.1	85.2	69.1	21.6
55c	Mad River Interlobate Area		Low Gradient	27	3.7	0.0	70.4	85.2	37.0
55d	Pre-Wisconsinan Drift Plains		Low Gradient	9	0.0	22.2	100.0	55.6	0.0
55e	Darby Plains		Low Gradient	30	0.0	0.0	100.0	76.7	16.7
57a	Maumee Lake Plain		Low Gradient	75	0.0	2.7	92.0	34.7	1.3
57b	Oak Openings		Low Gradient	15	0.0	0.0	93.3	40.0	0.0
57c	Paulding Plains		Low Gradient	13	7.7	7.7	76.9	38.5	0.0
57d	Marblehead Drift/Limestone Plain		Low Gradient	17	0.0	0.0	88.2	47.1	0.0
61b	Mosquito Creek/Pymatuning Lowlands		Low Gradient	7	0.0	28.6	85.7	28.6	14.3
61c	Low Lime Drift Plain		Low Gradient	109	2.7	0.0	91.7	64.2	21.1
61e	Summit Interlobate Area		Low Gradient	35	0.0	0.0	94.3	60.0	8.6
70b	Monongahela Transition Zone		Low Gradient	11	0.0	9.1	100.0	54.5	27.3
70d	Knobs-Lower Scioto Dissected Plateau		Low Gradient	10	10.0	10.0	70.0	40.0	10.0
70e	Unglaciated Upper Muskingum Basin		Low Gradient	32	0.0	0.0	96.9	53.1	6.2
70f	Ohio/Kentucky Carboniferous Plateau		Low Gradient	44	4.6	0.0	88.6	56.8	9.1