Appendices to:

Biological and Water Quality Study of the Brandywine Creek-Broken Sword Creek (Sandusky River) Study Area

2013

Hydrologic Unit Code (HUC)
04100011 03 01

Crawford County, Ohio

OHIO EPA Technical Report EAS/2015-03-02

Division of Surface Water
Ecological Assessment Section
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Appendices

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Appendix A

Qualitative Habitat Evaluation Index (QHEI) attributes and scores collected from the Broken Sword Creek basin, 2013.

Key QHEI Components

WWH Attributes | MWH Attributes

High Influence | *Moderate Influence*

River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current in Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	**Total H.L. MWH Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total M.L. MWH Attributes**	**(MWH HL+1)/(WWH+1) Ratio**	**(MWH ML+1)/(WWH+1) Ratio**
(05-035) Broken Sword Creek																																		
Year: 2013																																		
32.6	**42.0**	6.54	#										1	♦			♦	♦	♦	4	•		•			•	•	•				5	2.50	5.00
30.3	**56.5**	6.71	#								#		2	♦			♦	♦		3	•		•			•	•	•				5	1.33	3.00
27.9	**60.5**	2.61	#				#	#			#		4	♦						1	•		•	•			•	•				5	0.40	1.40
25.5	**49.3**	2.61	#				#	#			#		4	♦						1	•		•			•	•	•				5	0.40	1.40
19.7	**66.3**	2.87	#	#			#	#			#		5							0	•		•			•	•	•				5	0.17	1.00
(05-037) Brandywine Creek																																		
Year: 2013																																		
3.3	**66.0**	5.62	#	#		#	#	#	#		#		7							0		•		•				•	•				4	0.13	0.63
0.5	**44.0**	6.13									#		1		♦		♦	♦		3	•	•		•			•	•			•		6	2.00	5.00
(05-038) Red Run																																		
Year: 2013																																		
2.7	**19.5**	5.13									#		1	♦	♦		♦	♦		4		•		•		•	•	•	•				6	2.50	5.50
0.4	**45.5**	4.97	#										1	♦			♦	♦	♦	4	•	•		•			•	•	•				6	2.50	5.50
(05-095) Trib. to Broken Sword Creek (RM 28.04)																																		
Year: 2013																																		
0.4	**59.5**	9.26	#				#	#			#	#	5	♦			♦	♦		3	•	•		•				•	•				5	0.67	1.50

Appendix B

Fish scores for the Index of Biotic Integrity (IBI) and the Modified Index of well-being (MIwb) from the Broken Sword Creek basin, 2013.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Minnow species	Headwater species	Sensitive species	Darter & Sculpin species	Simple Lithophils	Percent of Individuals: Tolerant fishes	Omni-vores	Pioneering fishes	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)	IBI
Broken Sword Creek - (05-035)																
Year: 2013																
32.60	D	08/07/2013	4.1	13(5)	6(5)	2(3)	1(1)	3(5)	4(3)	29(5)	4(5)	28(5)	19(3)	0.0(5)	5114(5)	50
30.30	E	07/29/2013	9.4	17(5)	7(5)	1(1)	3(3)	5(5)	7(5)	57(3)	7(5)	48(3)	38(3)	0.0(5)	258(3)	46
Brandywine Creek - (05-037)																
Year: 2013																
3.30	E	07/23/2013	5.3	13(5)	7(5)	1(1)	1(1)	1(1)	2(1)	29(5)	18(3)	23(5)	17(1)	0.0(5)	1038(5)	38
0.50	D	08/07/2013	11.1	12(3)	5(3)	0(1)	0(1)	2(3)	2(1)	62(1)	17(3)	44(3)	74(5)	0.0(5)	83(1)	30
Red Run - (05-038)																
Year: 2013																
2.70	E	07/23/2013	4.3	8(3)	4(3)	0(1)	0(1)	1(1)	1(1)	75(1)	68(1)	11(5)	18(3)	1.0(3)	100(1)	24
0.40	E	07/29/2013	8.0	17(5)	9(5)	1(1)	0(1)	2(3)	4(3)	35(3)	16(3)	43(3)	16(1)	0.0(5)	2312(5)	38
Broken Sword trib - (05-095)																
Year: 2013																
0.40	E	07/29/2013	4.8	15(5)	7(5)	0(1)	0(1)	1(1)	2(1)	54(3)	4(5)	65(1)	38(5)	0.0(5)	274(3)	36

♦ - IBI is low end adjusted.

* - < 200 Total individuals in sample

** - < 50 Total individuals in sample

● - One or more species excluded from IBI calculation.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Sunfish species	Sucker species	Intolerant species	Darter species	Percent of Individuals: Simple Lithophils	Tolerant fishes	Omni-vores	Top carnivores	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)	IBI	Modified Iwb
Broken Sword Creek - (05035)																	
Year: 2013																	
28.00	D	07/24/2013	26	22(5)	2(3)	2(3)	0(1)	4(5)	23(3)	74(1)	55(1)	0.5(1)	30(3)	0.1(3)	582(3)	32	8.0
28.00	D	08/13/2013	26	22(5)	3(3)	2(3)	0(1)	5(5)	17(1)	68(1)	48(1)	1.3(3)	42(3)	0.0(5)	786(5)	36	8.3
25.50	D	07/24/2013	32	15(3)	2(3)	1(1)	0(1)	2(1)	12(1)	69(1)	12(5)	0.0(1)	56(5)	0.4(5)	114(1)	28	5.8
25.50	D	08/13/2013	32	18(3)	2(3)	1(1)	0(1)	3(3)	29(3)	57(1)	15(5)	0.0(1)	67(5)	0.0(5)	308(3)	34	7.6
19.70	D	07/24/2013	42	15(3)	2(3)	1(1)	0(1)	3(3)	7(1)	73(1)	49(1)	0.0(1)	38(3)	0.0(5)	294(3)	26	6.7
19.70	D	08/13/2013	42	17(3)	3(3)	1(1)	0(1)	3(3)	10(1)	72(1)	40(1)	0.7(1)	41(3)	0.0(5)	232(3)	26	6.2

na - Qualitative data, Modified Iwb not applicable.

♦ - IBI is low end adjusted.

* - < 200 Total individuals in sample

** - < 50 Total individuals in sample

● - One or more species excluded from IBI calculation.

Appendix C

Fish species and abundance for each sampling location from the Broken Sword Creek basin, 2013.

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **08/07/2013**
River Mile: **32.60**	Location:	Invalid Sample:
Time Fished: 2307 sec	Drainage: 4.1 sq mi Depth:	Data Source: 01
Dist Fished: 0.15 km	Basin: Sandusky River Flow: C	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	45	90.00	1.24			
Western Blacknose Dace	N	G	S	T	331	662.00	9.16			
Creek Chub	N	G	N	T	577	1,154.00	15.96			
Common Shiner	N	I	S		21	42.00	0.58			
Silverjaw Minnow	N	I	M		176	352.00	4.87			
Bluntnose Minnow	N	O	C	T	96	192.00	2.66			
Central Stoneroller	N	H	N		1,892	3,784.00	52.34			
Largemouth Bass	F	C	C		4	8.00	0.11			
Green Sunfish	S	I	C	T	9	18.00	0.25			
Bluegill Sunfish	S	I	C	P	25	50.00	0.69			
Johnny Darter	D	I	C		158	316.00	4.37			
Rainbow Darter	D	I	S	M	72	144.00	1.99			
Fantail Darter	D	I	C		209	418.00	5.78			
Date Total					3,615	7,230.00				
Number of Species					13					
Number of Hybrids					0					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **2013**
River Mile: **32.60**	Location:	Date Range: 08/07/2013
Time Fished: 2307 sec	Drainage: 4.1 sq mi	
Dist Fished: 0.15 km	Basin: Sandusky River No of Passes: 1	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	45	90.00	1.24			
Western Blacknose Dace	N	G	S	T	331	662.00	9.16			
Creek Chub	N	G	N	T	577	1,154.00	15.96			
Common Shiner	N	I	S		21	42.00	0.58			
Silverjaw Minnow	N	I	M		176	352.00	4.87			
Bluntnose Minnow	N	O	C	T	96	192.00	2.66			
Central Stoneroller	N	H	N		1,892	3,784.00	52.34			
Largemouth Bass	F	C	C		4	8.00	0.11			
Green Sunfish	S	I	C	T	9	18.00	0.25			
Bluegill Sunfish	S	I	C	P	25	50.00	0.69			
Johnny Darter	D	I	C		158	316.00	4.37			
Rainbow Darter	D	I	S	M	72	144.00	1.99			
Fantail Darter	D	I	C		209	418.00	5.78			
Mile Total					3,615	7,230.00				
Number of Species					13					
Number of Hybrids					0					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **07/29/2013**
River Mile: **30.30**	Location: Beck Rd.	Invalid Sample:
Time Fished: 1952 sec	Drainage: 9.4 sq mi Depth:	Data Source: 01
Dist Fished: 0.15 km	Basin: Sandusky River Flow: C	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	17	34.00	5.70			
Western Blacknose Dace	N	G	S	T	6	12.00	2.01			
Creek Chub	N	G	N	T	115	230.00	38.59			
Common Shiner	N	I	S		28	56.00	9.40			
Spotfin Shiner	N	I	M		1	2.00	0.34			
Silverjaw Minnow	N	I	M		1	2.00	0.34			
Bluntnose Minnow	N	O	C	T	4	8.00	1.34			
Central Stoneroller	N	H	N		43	86.00	14.43			
Yellow Bullhead		I	C	T	12	24.00	4.03			
Blackstripe Topminnow		I	M		21	42.00	7.05			
Green Sunfish	S	I	C	T	15	30.00	5.03			
Bluegill Sunfish	S	I	C	P	14	28.00	4.70			
Blackside Darter	D	I	S		8	16.00	2.68			
Logperch	D	I	S	M	1	2.00	0.34			
Johnny Darter	D	I	C		7	14.00	2.35			
Greenside Darter	D	I	S	M	1	2.00	0.34			
Rainbow Darter	D	I	S	M	4	8.00	1.34			
Date Total					298	596.00				
Number of Species					17					
Number of Hybrids					0					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **2013**
River Mile: **30.30**	Location: Beck Rd.	Date Range: 07/29/2013
Time Fished: 1952 sec	Drainage: 9.4 sq mi	
Dist Fished: 0.15 km	Basin: Sandusky River No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	17	34.00	5.70			
Western Blacknose Dace	N	G	S	T	6	12.00	2.01			
Creek Chub	N	G	N	T	115	230.00	38.59			
Common Shiner	N	I	S		28	56.00	9.40			
Spotfin Shiner	N	I	M		1	2.00	0.34			
Silverjaw Minnow	N	I	M		1	2.00	0.34			
Bluntnose Minnow	N	O	C	T	4	8.00	1.34			
Central Stoneroller	N	H	N		43	86.00	14.43			
Yellow Bullhead		I	C	T	12	24.00	4.03			
Blackstripe Topminnow		I	M		21	42.00	7.05			
Green Sunfish	S	I	C	T	15	30.00	5.03			
Bluegill Sunfish	S	I	C	P	14	28.00	4.70			
Blackside Darter	D	I	S		8	16.00	2.68			
Logperch	D	I	S	M	1	2.00	0.34			
Johnny Darter	D	I	C		7	14.00	2.35			
Greenside Darter	D	I	S	M	1	2.00	0.34			
Rainbow Darter	D	I	S	M	4	8.00	1.34			
Mile Total					298	596.00				
Number of Species					17					
Number of Hybrids					0					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **07/24/2013**
River Mile: **28.00**	Location: Ridgeton-Annapolis Rd. (Co. Rd. 78)	Invalid Sample:
Time Fished: 2599 sec	Drainage: 26.6 sq mi Depth:	Data Source: 01
Dist Fished: 0.20 km	Basin: Sandusky River Flow: C	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	183	274.50	12.48	16.65	37.73	60.66
Spotted Sucker	R	I	S		1	1.50	0.07	0.05	0.12	35.00
Common Carp	G	O	M	T	4	6.00	0.27	7.16	16.21	1,192.50
Western Blacknose Dace	N	G	S	T	1	1.50	0.07	0.00	0.01	2.00
Creek Chub	N	G	N	T	167	250.50	11.39	5.68	12.86	22.65
Redfin Shiner	N	I	N		9	13.50	0.61	0.04	0.09	2.78
Striped Shiner	N	I	S		2	3.00	0.14	0.02	0.04	6.00
Common Shiner	N	I	S		135	202.50	9.21	2.44	5.52	12.03
Spotfin Shiner	N	I	M		17	25.50	1.16	0.10	0.24	4.06
Silverjaw Minnow	N	I	M		78	117.00	5.32	0.21	0.46	1.75
Fathead Minnow	N	O	C	T	8	12.00	0.55	0.02	0.03	1.25
Bluntnose Minnow	N	O	C	T	610	915.00	41.61	2.16	4.90	2.36
Central Stoneroller	N	H	N		39	58.50	2.66	1.06	2.39	18.06
Yellow Bullhead		I	C	T	68	102.00	4.64	5.55	12.58	54.41
Brown Bullhead		I	C	T	3	4.50	0.20	0.64	1.45	141.67
Blackstripe Topminnow		I	M		28	42.00	1.91	0.05	0.11	1.20
Largemouth Bass	F	C	C		7	10.50	0.48	0.03	0.07	3.00
Green Sunfish	S	I	C	T	34	51.00	2.32	0.71	1.61	13.94
Bluegill Sunfish	S	I	C	P	48	72.00	3.27	1.52	3.43	21.04
Blackside Darter	D	I	S		3	4.50	0.20	0.02	0.05	5.00
Johnny Darter	D	I	C		16	24.00	1.09	0.02	0.05	1.00
Greenside Darter	D	I	S	M	1	1.50	0.07	0.00	0.00	1.00
Rainbow Darter	D	I	S	M	4	6.00	0.27	0.02	0.03	2.50
Date Total					1,466	2,199.00		44.13		
Number of Species					23					
Number of Hybrids					0					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **08/13/2013**
River Mile: **28.00**	Location: Ridgeton-Annapolis Rd. (Co. Rd. 78)	Invalid Sample:
Time Fished: 2325 sec	Drainage: 26.6 sq mi Depth:	Data Source: 01
Dist Fished: 0.20 km	Basin: Sandusky River Flow: C	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	168	252.00	10.29	18.83	42.31	74.70
Spotted Sucker	R	I	S		1	1.50	0.06	0.08	0.17	50.00
Common Carp	G	O	M	T	3	4.50	0.18	1.53	3.44	340.00
Western Blacknose Dace	N	G	S	T	1	1.50	0.06	0.01	0.01	3.00
Creek Chub	N	G	N	T	130	195.00	7.97	5.18	11.64	26.56
Redfin Shiner	N	I	N		9	13.50	0.55	0.03	0.07	2.22
Striped Shiner	N	I	S		84	126.00	5.15	2.55	5.73	20.24
Spotfin Shiner	N	I	M		22	33.00	1.35	0.08	0.17	2.27
Silverjaw Minnow	N	I	M		160	240.00	9.80	0.44	0.99	1.84
Bluntnose Minnow	N	O	C	T	613	919.50	37.56	1.66	3.73	1.81
Central Stoneroller	N	H	N		15	22.50	0.92	0.41	0.92	18.14
Yellow Bullhead		I	C	T	94	141.00	5.76	8.57	19.27	60.79
Brown Bullhead		I	C	T	4	6.00	0.25	0.74	1.65	122.50
Blackstripe Topminnow		I	M		36	54.00	2.21	0.11	0.24	2.00
Rock Bass	S	C	C		3	4.50	0.18	0.14	0.32	31.67
Largemouth Bass	F	C	C		18	27.00	1.10	0.37	0.82	13.53
Green Sunfish	S	I	C	T	95	142.50	5.82	1.49	3.34	10.43
Bluegill Sunfish	S	I	C	P	115	172.50	7.05	1.86	4.19	10.81
Green Sf X Bluegill Sf					2	3.00	0.12	0.13	0.28	42.00
Blackside Darter	D	I	S		21	31.50	1.29	0.14	0.30	4.29
Logperch	D	I	S	M	5	7.50	0.31	0.09	0.20	12.00
Johnny Darter	D	I	C		30	45.00	1.84	0.06	0.14	1.38
Greenside Darter	D	I	S	M	2	3.00	0.12	0.02	0.05	7.50
Rainbow Darter	D	I	S	M	1	1.50	0.06	0.01	0.01	3.00
Date Total					1,632	2,448.00		44.49		
Number of Species					23					
Number of Hybrids					1					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **2013**
River Mile: **28.00**	Location: Ridgeton-Annapolis Rd. (Co. Rd. 78)	Date Range: 07/24/2013
Time Fished: 4924 sec	Drainage: 26.6 sq mi	Thru: 08/13/2013
Dist Fished: 0.40 km	Basin: Sandusky River No of Passes: 2	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	351	263.25	11.33	17.74	40.03	67.38
Spotted Sucker	R	I	S		2	1.50	0.06	0.06	0.14	42.50
Common Carp	G	O	M	T	7	5.25	0.23	4.34	9.80	827.14
Western Blacknose Dace	N	G	S	T	2	1.50	0.06	0.00	0.01	2.50
Creek Chub	N	G	N	T	297	222.75	9.59	5.43	12.25	24.36
Redfin Shiner	N	I	N		18	13.50	0.58	0.03	0.08	2.50
Striped Shiner	N	I	S		86	64.50	2.78	1.28	2.90	19.91
Common Shiner	N	I	S		135	101.25	4.36	1.22	2.75	12.03
Spotfin Shiner	N	I	M		39	29.25	1.26	0.09	0.20	3.05
Silverjaw Minnow	N	I	M		238	178.50	7.68	0.32	0.73	1.81
Fathead Minnow	N	O	C	T	8	6.00	0.26	0.01	0.02	1.25
Bluntnose Minnow	N	O	C	T	1,223	917.25	39.48	1.91	4.32	2.08
Central Stoneroller	N	H	N		54	40.50	1.74	0.73	1.65	18.08
Yellow Bullhead		I	C	T	162	121.50	5.23	7.06	15.93	58.11
Brown Bullhead		I	C	T	7	5.25	0.23	0.69	1.55	130.71
Blackstripe Topminnow		I	M		64	48.00	2.07	0.08	0.18	1.65
Rock Bass	S	C	C		3	2.25	0.10	0.07	0.16	31.67
Largemouth Bass	F	C	C		25	18.75	0.81	0.20	0.45	10.58
Green Sunfish	S	I	C	T	129	96.75	4.16	1.10	2.48	11.35
Bluegill Sunfish	S	I	C	P	163	122.25	5.26	1.69	3.81	13.82
Green Sf X Bluegill Sf					2	1.50	0.06	0.06	0.14	42.00
Blackside Darter	D	I	S		24	18.00	0.77	0.08	0.18	4.38
Logperch	D	I	S	M	5	3.75	0.16	0.05	0.10	12.00
Johnny Darter	D	I	C		46	34.50	1.48	0.04	0.10	1.25
Greenside Darter	D	I	S	M	3	2.25	0.10	0.01	0.03	5.33
Rainbow Darter	D	I	S	M	5	3.75	0.16	0.01	0.02	2.60
	Mile Total				3,098	2,323.50		44.31		
	Number of Species				25					
	Number of Hybrids				1					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **07/24/2013**
River Mile: **25.50**	Location: Schwemley Rd.	Invalid Sample:
Time Fished: 2323 sec	Drainage: 32.6 sq mi Depth:	Data Source: 01
Dist Fished: 0.20 km	Basin: Sandusky River Flow: C	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	5	7.50	2.07	0.09	1.91	12.00
Western Blacknose Dace	N	G	S	T	5	7.50	2.07	0.01	0.19	1.20
Creek Chub	N	G	N	T	65	97.50	26.86	2.20	46.82	22.58
Redfin Shiner	N	I	N		3	4.50	1.24	0.02	0.49	5.00
Common Shiner	N	I	S		17	25.50	7.02	0.24	5.08	9.38
Spotfin Shiner	N	I	M		5	7.50	2.07	0.04	0.81	5.00
Silverjaw Minnow	N	I	M		6	9.00	2.48	0.03	0.68	3.60
Bluntnose Minnow	N	O	C	T	25	37.50	10.33	0.05	0.96	1.20
Central Stoneroller	N	H	N		5	7.50	2.07	0.02	0.32	2.00
Yellow Bullhead		I	C	T	22	33.00	9.09	1.40	29.66	42.27
Blackstripe Topminnow		I	M		25	37.50	10.33	0.06	1.34	1.67
Green Sunfish	S	I	C	T	44	66.00	18.18	0.38	8.17	5.81
Bluegill Sunfish	S	I	C	P	3	4.50	1.24	0.02	0.49	5.00
Green Sf X Bluegill Sf					1	1.50	0.41	0.06	1.28	40.00
Blackside Darter	D	I	S		2	3.00	0.83	0.04	0.89	14.00
Johnny Darter	D	I	C		9	13.50	3.72	0.05	0.96	3.33
	Date Total				242	363.00		4.70		
	Number of Species				15					
	Number of Hybrids				1					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **08/13/2013**
River Mile: **25.50**	Location: Schwemley Rd.	Invalid Sample:
Time Fished: 1630 sec	Drainage: 32.6 sq mi Depth:	Data Source: 01
Dist Fished: 0.20 km	Basin: Sandusky River Flow: C	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	11	16.50	2.30	0.96	12.39	58.18
Common Carp	G	O	M	T	1	1.50	0.21	0.03	0.34	17.00
Western Blacknose Dace	N	G	S	T	2	3.00	0.42	0.01	0.08	2.00
Creek Chub	N	G	N	T	65	97.50	13.60	1.69	21.80	17.32
Redfin Shiner	N	I	N		7	10.50	1.46	0.02	0.27	2.00
Common Shiner	N	I	S		119	178.50	24.90	2.55	32.88	14.27
Spotfin Shiner	N	I	M		7	10.50	1.46	0.02	0.27	2.00
Silverjaw Minnow	N	I	M		13	19.50	2.72	0.03	0.43	1.69
Fathead Minnow	N	O	C	T	15	22.50	3.14	0.07	0.85	2.92
Bluntnose Minnow	N	O	C	T	46	69.00	9.62	0.42	5.42	6.09
Central Stoneroller	N	H	N		19	28.50	3.97	0.14	1.85	5.00
Yellow Bullhead		I	C	T	56	84.00	11.72	0.48	6.14	5.67
Brown Bullhead		I	C	T	1	1.50	0.21	0.26	3.39	175.00
Blackstripe Topminnow		I	M		21	31.50	4.39	0.03	0.41	1.00
Green Sunfish	S	I	C	T	76	114.00	15.90	0.97	12.53	8.51
Bluegill Sunfish	S	I	C	P	3	4.50	0.63	0.02	0.30	5.00
Blackside Darter	D	I	S		4	6.00	0.84	0.01	0.15	2.00
Logperch	D	I	S	M	1	1.50	0.21	0.02	0.30	15.00
Johnny Darter	D	I	C		11	16.50	2.30	0.02	0.26	1.20
	Date Total				478	717.00		7.75		
	Number of Species				19					
	Number of Hybrids				0					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **2013**
River Mile: **25.50**	Location: Schwemley Rd.	Date Range: 07/24/2013
Time Fished: 3953 sec	Drainage: 32.6 sq mi	Thru: 08/13/2013
Dist Fished: 0.40 km	Basin: Sandusky River No of Passes: 2	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	16	12.00	2.22	0.53	8.43	43.75
Common Carp	G	O	M	T	1	0.75	0.14	0.01	0.21	17.00
Western Blacknose Dace	N	G	S	T	7	5.25	0.97	0.01	0.12	1.43
Creek Chub	N	G	N	T	130	97.50	18.06	1.95	31.25	19.95
Redfin Shiner	N	I	N		10	7.50	1.39	0.02	0.35	2.90
Common Shiner	N	I	S		136	102.00	18.89	1.39	22.38	13.66
Spotfin Shiner	N	I	M		12	9.00	1.67	0.03	0.47	3.25
Silverjaw Minnow	N	I	M		19	14.25	2.64	0.03	0.52	2.29
Fathead Minnow	N	O	C	T	15	11.25	2.08	0.03	0.53	2.92
Bluntnose Minnow	N	O	C	T	71	53.25	9.86	0.23	3.73	4.37
Central Stoneroller	N	H	N		24	18.00	3.33	0.08	1.27	4.38
Yellow Bullhead		I	C	T	78	58.50	10.83	0.94	15.03	15.99
Brown Bullhead		I	C	T	1	0.75	0.14	0.13	2.11	175.00
Blackstripe Topminnow		I	M		46	34.50	6.39	0.05	0.76	1.36
Green Sunfish	S	I	C	T	120	90.00	16.67	0.68	10.88	7.52
Bluegill Sunfish	S	I	C	P	6	4.50	0.83	0.02	0.37	5.00
Green Sf X Bluegill Sf					1	0.75	0.14	0.03	0.48	40.00
Blackside Darter	D	I	S		6	4.50	0.83	0.03	0.43	6.00
Logperch	D	I	S	M	1	0.75	0.14	0.01	0.18	15.00
Johnny Darter	D	I	C		20	15.00	2.78	0.03	0.52	2.16
	Mile Total				720	540.00		6.23		
	Number of Species				19					
	Number of Hybrids				1					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **07/24/2013**
River Mile: **19.70**	Location: St. Rts. 19/100	Invalid Sample:
Time Fished: 2483 sec	Drainage: 42.0 sq mi Depth:	Data Source: 01
Dist Fished: 0.15 km	Basin: Sandusky River Flow: C	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	4	8.00	0.74	0.08	1.33	10.00
Common Carp	G	O	M	T	1	2.00	0.19	0.00	0.07	2.00
Western Blacknose Dace	N	G	S	T	10	20.00	1.86	0.05	0.83	2.50
Creek Chub	N	G	N	T	25	50.00	4.65	0.88	14.60	17.60
Redfin Shiner	N	I	N		28	56.00	5.20	0.08	1.38	1.48
Common Shiner	N	I	S		9	18.00	1.67	0.11	1.83	6.11
Spotfin Shiner	N	I	M		34	68.00	6.32	0.14	2.32	2.06
Silverjaw Minnow	N	I	M		7	14.00	1.30	0.06	0.93	4.00
Bluntnose Minnow	N	O	C	T	260	520.00	48.33	0.68	11.28	1.31
Central Stoneroller	N	H	N		34	68.00	6.32	0.13	2.09	1.85
Yellow Bullhead		I	C	T	18	36.00	3.35	2.20	36.51	61.11
Green Sunfish	S	I	C	T	73	146.00	13.57	1.05	17.41	7.18
Bluegill Sunfish	S	I	C	P	15	30.00	2.79	0.38	6.31	12.67
Blackside Darter	D	I	S		8	16.00	1.49	0.09	1.53	5.75
Johnny Darter	D	I	C		7	14.00	1.30	0.05	0.78	3.33
Greenside Darter	D	I	S	M	5	10.00	0.93	0.05	0.83	5.00
	Date Total				538	1,076.00		6.03		
	Number of Species				16					
	Number of Hybrids				0					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **08/13/2013**
River Mile: **19.70**	Location: St. Rts. 19/100	Invalid Sample:
Time Fished: 1753 sec	Drainage: 42.0 sq mi Depth:	Data Source: 01
Dist Fished: 0.15 km	Basin: Sandusky River Flow: C	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	3	6.00	0.74	0.04	0.77	6.67
Western Blacknose Dace	N	G	S	T	21	42.00	5.15	0.05	0.97	1.20
Creek Chub	N	G	N	T	26	52.00	6.37	0.73	14.09	14.00
Redfin Shiner	N	I	N		9	18.00	2.21	0.01	0.27	0.75
Common Shiner	N	I	S		8	16.00	1.96	0.26	5.03	16.25
Spotfin Shiner	N	I	M		50	100.00	12.25	0.15	2.96	1.53
Bluntnose Minnow	N	O	C	T	159	318.00	38.97	0.34	6.54	1.06
Central Stoneroller	N	H	N		28	56.00	6.86	0.08	1.47	1.36
Yellow Bullhead		I	C	T	39	78.00	9.56	2.51	48.57	32.18
Blackstripe Topminnow		I	M		3	6.00	0.74	0.01	0.19	1.67
Rock Bass	S	C	C		1	2.00	0.25	0.02	0.31	8.00
Largemouth Bass	F	C	C		2	4.00	0.49	0.01	0.19	2.50
Green Sunfish	S	I	C	T	44	88.00	10.78	0.89	17.22	10.12
Bluegill Sunfish	S	I	C	P	3	6.00	0.74	0.02	0.46	4.00
Blackside Darter	D	I	S		6	12.00	1.47	0.02	0.46	2.00
Johnny Darter	D	I	C		5	10.00	1.23	0.02	0.39	2.00
Greenside Darter	D	I	S	M	1	2.00	0.25	0.00	0.08	2.00
	Date Total				408	816.00		5.17		
	Number of Species				17					
	Number of Hybrids				0					

River Code: **05-035**	Stream: **Broken Sword Creek**	Sample Date: **2013**
River Mile: **19.70**	Location: St. Rts. 19/100	Date Range: 07/24/2013
Time Fished: 4236 sec	Drainage: 42.0 sq mi	Thru: 08/13/2013
Dist Fished: 0.30 km	Basin: Sandusky River No of Passes: 2	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	7	7.00	0.74	0.06	1.07	8.57
Common Carp	G	O	M	T	1	1.00	0.11	0.00	0.04	2.00
Western Blacknose Dace	N	G	S	T	31	31.00	3.28	0.05	0.89	1.62
Creek Chub	N	G	N	T	51	51.00	5.39	0.80	14.36	15.76
Redfin Shiner	N	I	N		37	37.00	3.91	0.05	0.87	1.30
Common Shiner	N	I	S		17	17.00	1.80	0.19	3.31	10.88
Spotfin Shiner	N	I	M		84	84.00	8.88	0.15	2.62	1.74
Silverjaw Minnow	N	I	M		7	7.00	0.74	0.03	0.50	4.00
Bluntnose Minnow	N	O	C	T	419	419.00	44.29	0.51	9.09	1.22
Central Stoneroller	N	H	N		62	62.00	6.55	0.10	1.80	1.63
Yellow Bullhead		I	C	T	57	57.00	6.03	2.36	42.08	41.32
Blackstripe Topminnow		I	M		3	3.00	0.32	0.01	0.09	1.67
Rock Bass	S	C	C		1	1.00	0.11	0.01	0.14	8.00
Largemouth Bass	F	C	C		2	2.00	0.21	0.01	0.09	2.50
Green Sunfish	S	I	C	T	117	117.00	12.37	0.97	17.32	8.29
Bluegill Sunfish	S	I	C	P	18	18.00	1.90	0.20	3.61	11.22
Blackside Darter	D	I	S		14	14.00	1.48	0.06	1.04	4.14
Johnny Darter	D	I	C		12	12.00	1.27	0.03	0.60	2.78
Greenside Darter	D	I	S	M	6	6.00	0.63	0.03	0.48	4.50
Mile Total					946	946.00		5.60		
Number of Species					19					
Number of Hybrids					0					

River Code: **05-037**	Stream: **Brandywine Creek**	Sample Date: **07/23/2013**
River Mile: **3.30**	Location: Spore-Brandywine Rd.	Invalid Sample:
Time Fished: 2144 sec	Drainage: 5.3 sq mi Depth:	Data Source: 01
Dist Fished: 0.15 km	Basin: Sandusky River Flow: C	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	41	82.00	5.62			
Western Blacknose Dace	N	G	S	T	1	2.00	0.14			
Creek Chub	N	G	N	T	75	150.00	10.29			
Redfin Shiner	N	I	N		13	26.00	1.78			
Silverjaw Minnow	N	I	M		1	2.00	0.14			
Fathead Minnow	N	O	C	T	72	144.00	9.88			
Bluntnose Minnow	N	O	C	T	17	34.00	2.33			
Central Stoneroller	N	H	N		400	800.00	54.87			
Largemouth Bass	F	C	C		3	6.00	0.41			
Green Sunfish	S	I	C	T	4	8.00	0.55			
Bluegill Sunfish	S	I	C	P	79	158.00	10.84			
Longear Sunfish	S	I	C	M	22	44.00	3.02			
Johnny Darter	D	I	C		1	2.00	0.14			
Date Total					729	1,458.00				
Number of Species					13					
Number of Hybrids					0					

River Code: **05-037**	Stream: **Brandywine Creek**	Sample Date: **2013**
River Mile: **3.30**	Location: Spore-Brandywine Rd.	Date Range: 07/23/2013
Time Fished: 2144 sec	Drainage: 5.3 sq mi	
Dist Fished: 0.15 km	Basin: Sandusky River No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	41	82.00	5.62			
Western Blacknose Dace	N	G	S	T	1	2.00	0.14			
Creek Chub	N	G	N	T	75	150.00	10.29			
Redfin Shiner	N	I	N		13	26.00	1.78			
Silverjaw Minnow	N	I	M		1	2.00	0.14			
Fathead Minnow	N	O	C	T	72	144.00	9.88			
Bluntnose Minnow	N	O	C	T	17	34.00	2.33			
Central Stoneroller	N	H	N		400	800.00	54.87			
Largemouth Bass	F	C	C		3	6.00	0.41			
Green Sunfish	S	I	C	T	4	8.00	0.55			
Bluegill Sunfish	S	I	C	P	79	158.00	10.84			
Longear Sunfish	S	I	C	M	22	44.00	3.02			
Johnny Darter	D	I	C		1	2.00	0.14			
Mile Total					729	1,458.00				
Number of Species					13					
Number of Hybrids					0					

River Code: **05-037**	Stream: **Brandywine Creek**	Sample Date: **08/07/2013**
River Mile: **0.50**	Location:	Invalid Sample:
Time Fished: 1556 sec	Drainage: 11.1 sq mi Depth:	Data Source: 01
Dist Fished: 0.20 km	Basin: Sandusky River Flow: C	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	18	27.00	12.59	0.05	2.88	1.67
Golden Shiner	N	I	M	T	1	1.50	0.70	0.02	0.96	10.00
Creek Chub	N	G	N	T	11	16.50	7.69	0.45	28.75	27.27
Redfin Shiner	N	I	N		15	22.50	10.49	0.01	0.77	0.53
Bluntnose Minnow	N	O	C	T	6	9.00	4.20	0.02	1.47	2.50
Central Stoneroller	N	H	N		2	3.00	1.40	0.07	4.35	22.50
Yellow Bullhead		I	C	T	7	10.50	4.90	0.09	5.75	8.57
Blackstripe Topminnow		I	M		16	24.00	11.19	0.05	2.88	1.88
Green Sunfish	S	I	C	T	45	67.50	31.47	0.59	37.38	8.67
Bluegill Sunfish	S	I	C	P	19	28.50	13.29	0.22	13.93	7.63
Blackside Darter	D	I	S		2	3.00	1.40	0.01	0.77	4.00
Johnny Darter	D	I	C		1	1.50	0.70	0.00	0.19	2.00
Date Total					143	214.50		1.57		
Number of Species					12					
Number of Hybrids					0					

River Code: **05-037**	Stream: **Brandywine Creek**	Sample Date: **2013**
River Mile: **0.50**	Location:	Date Range: 08/07/2013
Time Fished: 1556 sec	Drainage: 11.1 sq mi	
Dist Fished: 0.20 km	Basin: Sandusky River No of Passes: 1	Sampler Type: D

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	18	27.00	12.59	0.05	2.88	1.67
Golden Shiner	N	I	M	T	1	1.50	0.70	0.02	0.96	10.00
Creek Chub	N	G	N	T	11	16.50	7.69	0.45	28.75	27.27
Redfin Shiner	N	I	N		15	22.50	10.49	0.01	0.77	0.53
Bluntnose Minnow	N	O	C	T	6	9.00	4.20	0.02	1.47	2.50
Central Stoneroller	N	H	N		2	3.00	1.40	0.07	4.35	22.50
Yellow Bullhead		I	C	T	7	10.50	4.90	0.09	5.75	8.57
Blackstripe Topminnow		I	M		16	24.00	11.19	0.05	2.88	1.88
Green Sunfish	S	I	C	T	45	67.50	31.47	0.59	37.38	8.67
Bluegill Sunfish	S	I	C	P	19	28.50	13.29	0.22	13.93	7.63
Blackside Darter	D	I	S		2	3.00	1.40	0.01	0.77	4.00
Johnny Darter	D	I	C		1	1.50	0.70	0.00	0.19	2.00
	Mile Total				143	214.50		1.57		
	Number of Species				12					
	Number of Hybrids				0					

River Code: **05-038**	Stream: **Red Run**	Sample Date: **07/23/2013**
River Mile: **2.70**	Location:	Invalid Sample:
Time Fished: 2063 sec	Drainage: 4.3 sq mi	Depth:	Data Source: 01
Dist Fished: 0.15 km	Basin: Sandusky River	Flow: C	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Common Carp	G	O	M	T	131	262.00	64.53			
Creek Chub	N	G	N	T	16	32.00	7.88			
Common Shiner	N	I	S		1	2.00	0.49			
Fathead Minnow	N	O	C	T	6	12.00	2.96			
Central Stoneroller	N	H	N		1	2.00	0.49			
Blackstripe Topminnow		I	M		27	54.00	13.30			
Largemouth Bass	F	C	C		12	24.00	5.91			
Bluegill Sunfish	S	I	C	P	8	16.00	3.94			
Johnny Darter	D	I	C		1	2.00	0.49			
Date Total					203	406.00				
Number of Species					9					
Number of Hybrids					0					

River Code: **05-038**	Stream: **Red Run**	Sample Date: **2013**
River Mile: **2.70**	Location:	Date Range: 07/23/2013
Time Fished: 2063 sec	Drainage: 4.3 sq mi	
Dist Fished: 0.15 km	Basin: Sandusky River No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
Common Carp	G	O	M	T	131	262.00	64.53			
Creek Chub	N	G	N	T	16	32.00	7.88			
Common Shiner	N	I	S		1	2.00	0.49			
Fathead Minnow	N	O	C	T	6	12.00	2.96			
Central Stoneroller	N	H	N		1	2.00	0.49			
Blackstripe Topminnow		I	M		27	54.00	13.30			
Largemouth Bass	F	C	C		12	24.00	5.91			
Bluegill Sunfish	S	I	C	P	8	16.00	3.94			
Johnny Darter	D	I	C		1	2.00	0.49			
Mile Total					203	406.00				
Number of Species					9					
Number of Hybrids					0					

River Code: **05-038**	Stream: **Red Run**	Sample Date: **07/29/2013**
River Mile: **0.40**	Location:	Invalid Sample:
Time Fished: 1787 sec	Drainage: 8.0 sq mi	Depth:	Data Source: 01
Dist Fished: 0.15 km	Basin: Sandusky River	Flow: C	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	14	28.00	0.79			
Creek Chubsucker	R	I	M		1	2.00	0.06			
Common Carp	G	O	M	T	6	12.00	0.34			
Western Blacknose Dace	N	G	S	T	48	96.00	2.72			
Creek Chub	N	G	N	T	267	534.00	15.12			
Redfin Shiner	N	I	N		12	24.00	0.68			
Common Shiner	N	I	S		7	14.00	0.40			
Spotfin Shiner	N	I	M		3	6.00	0.17			
Silverjaw Minnow	N	I	M		82	164.00	4.64			
Fathead Minnow	N	O	C	T	4	8.00	0.23			
Bluntnose Minnow	N	O	C	T	266	532.00	15.06			
Central Stoneroller	N	H	N		879	1,758.00	49.77			
Blackstripe Topminnow		I	M		15	30.00	0.85			
Largemouth Bass	F	C	C		9	18.00	0.51			
Green Sunfish	S	I	C	T	5	10.00	0.28			
Bluegill Sunfish	S	I	C	P	3	6.00	0.17			
Blackside Darter	D	I	S		8	16.00	0.45			
Johnny Darter	D	I	C		137	274.00	7.76			
Date Total					1,766	3,532.00				
Number of Species					18					
Number of Hybrids					0					

River Code: **05-038**	Stream: **Red Run**	Sample Date: **2013**
River Mile: **0.40**	Location:	Date Range: 07/29/2013
Time Fished: 1787 sec	Drainage: 8.0 sq mi	
Dist Fished: 0.15 km	Basin: Sandusky River No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	14	28.00	0.79			
Creek Chubsucker	R	I	M		1	2.00	0.06			
Common Carp	G	O	M	T	6	12.00	0.34			
Western Blacknose Dace	N	G	S	T	48	96.00	2.72			
Creek Chub	N	G	N	T	267	534.00	15.12			
Redfin Shiner	N	I	N		12	24.00	0.68			
Common Shiner	N	I	S		7	14.00	0.40			
Spotfin Shiner	N	I	M		3	6.00	0.17			
Silverjaw Minnow	N	I	M		82	164.00	4.64			
Fathead Minnow	N	O	C	T	4	8.00	0.23			
Bluntnose Minnow	N	O	C	T	266	532.00	15.06			
Central Stoneroller	N	H	N		879	1,758.00	49.77			
Blackstripe Topminnow		I	M		15	30.00	0.85			
Largemouth Bass	F	C	C		9	18.00	0.51			
Green Sunfish	S	I	C	T	5	10.00	0.28			
Bluegill Sunfish	S	I	C	P	3	6.00	0.17			
Blackside Darter	D	I	S		8	16.00	0.45			
Johnny Darter	D	I	C		137	274.00	7.76			
Mile Total					1,766	3,532.00				
Number of Species					18					
Number of Hybrids					0					

River Code: **05-095**	Stream: **Trib. to Broken Sword Creek (RM 28.04)**	Sample Date: **07/29/2013**
River Mile: **0.40**	Location:	Invalid Sample:
Time Fished: 1368 sec	Drainage: 4.8 sq mi Depth:	Data Source: 01
Dist Fished: 0.15 km	Basin: Sandusky River Flow: C	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	2	4.00	0.67			
Creek Chub	N	G	N	T	124	248.00	41.75			
Redfin Shiner	N	I	N		3	6.00	1.01			
Common Shiner	N	I	S		23	46.00	7.74			
Silverjaw Minnow	N	I	M		46	92.00	15.49			
Fathead Minnow	N	O	C	T	3	6.00	1.01			
Bluntnose Minnow	N	O	C	T	7	14.00	2.36			
Central Stoneroller	N	H	N		46	92.00	15.49			
Yellow Bullhead		I	C	T	12	24.00	4.04			
Brown Bullhead		I	C	T	2	4.00	0.67			
Blackstripe Topminnow		I	M		13	26.00	4.38			
Largemouth Bass	F	C	C		3	6.00	1.01			
Green Sunfish	S	I	C	T	10	20.00	3.37			
Bluegill Sunfish	S	I	C	P	1	2.00	0.34			
Johnny Darter	D	I	C		2	4.00	0.67			
Date Total					297	594.00				
Number of Species					15					
Number of Hybrids					0					

River Code: **05-095**	Stream: **Trib. to Broken Sword Creek (RM 28.04)**	Sample Date: **2013**
River Mile: **0.40**	Location:	Date Range: 07/29/2013
Time Fished: 1368 sec	Drainage: 4.8 sq mi	
Dist Fished: 0.15 km	Basin: Sandusky River No of Passes: 1	Sampler Type: E

Species Name / ODNR status	IBI Grp	Feed Guild	Breed Guild	Tol	# of Fish	Relative Number	% by Number	Relative Weight	% by Weight	Ave(gm) Weight
White Sucker	W	O	S	T	2	4.00	0.67			
Creek Chub	N	G	N	T	124	248.00	41.75			
Redfin Shiner	N	I	N		3	6.00	1.01			
Common Shiner	N	I	S		23	46.00	7.74			
Silverjaw Minnow	N	I	M		46	92.00	15.49			
Fathead Minnow	N	O	C	T	3	6.00	1.01			
Bluntnose Minnow	N	O	C	T	7	14.00	2.36			
Central Stoneroller	N	H	N		46	92.00	15.49			
Yellow Bullhead		I	C	T	12	24.00	4.04			
Brown Bullhead		I	C	T	2	4.00	0.67			
Blackstripe Topminnow		I	M		13	26.00	4.38			
Largemouth Bass	F	C	C		3	6.00	1.01			
Green Sunfish	S	I	C	T	10	20.00	3.37			
Bluegill Sunfish	S	I	C	P	1	2.00	0.34			
Johnny Darter	D	I	C		2	4.00	0.67			
Mile Total					297	594.00				
Number of Species					15					
Number of Hybrids					0					

Appendix D

Macroinvertebrate ICI scores and metrics from the Broken Sword Creek basin, 2013.

River Mile	Drainage Area (sq mi)	Number of				Percent:					Qual. EPT	Eco-region	ICI
		Total Taxa	Mayfly Taxa	Caddisfly Taxa	Dipteran Taxa	Mayflies	Caddis-flies	Tany-tarsini	Other Dipt/NI	Tolerant Organisms			
Broken Sword Creek (05-035)													
Year: 2013													
27.96	26.6	28(4)	3(2)	2(4)	16(4)	2.2(2)	1.1(2)	28.6(6)	68.0(0)	19.0(2)	5(2)	5	28
25.48	32.6	32(4)	0(0)	2(4)	20(6)	0.0(0)	0.2(2)	11.7(2)	87.7(0)	48.8(0)	3(0)	5	18
19.70	42.0	28(4)	0(0)	3(4)	18(4)	0.0(0)	0.6(2)	7.0(2)	90.5(0)	36.2(0)	3(0)	5	16

Appendix E

Macroinvertebrate taxa lists from the Broken Sword Creek basin, 2013.

River Mile	All Taxa			Sen. Taxa			EPT Taxa		CW Taxa	Ql. Tol. Taxa	Ql. S T	QCTV	ICI	Nar.	Drain	Comments
	Total	Qt.	Ql.	Total	Qt.	Ql.	Total	Ql.								
Broken Sword Creek (05-035)																
Year: 2013																
32.60	40		40	4		4		3	1	13	0.31	37.1			4.4	
30.31	34		34	3		3		3	1	10	0.30	35.7			9.4	
27.96	58	28	48	3	1	3	7	5	0	19	0.16	34.3	28		26.6	X15
25.48	50	32	34	4	0	4	4	3	0	14	0.29	34.3	18		32.6	
19.70	51	28	31	2	2	0	6	3	1	12	0.00	34.5	16		42.0	
Brandywine Creek (05-037)																
Year: 2013																
3.30	25		25	0		0		1	1	16	0.00	33.8			5.3	
0.80	35		35	0		0		2	1	16	0.00	34.3			10.9	
0.45	24		24	1		1		1	0	14	0.07	29.2			11.1	
Red Run (05-038)																
Year: 2013																
2.65	25		25	0		0		0	1	18	0.00	26.7			4.3	
0.42	35		35	2		2		4	0	17	0.12	34.6			8.0	
Trib. to Broken Sword Creek (RM 28.04) (05-095)																
Year: 2013																
0.36	34		34	1		1		3	1	17	0.06	33.8			4.8	

Appendix F

Notice to users, biosurvey background information, mechanisms for water quality impairment, and methods.

NOTICE TO USERS

Ohio EPA incorporated biological criteria into the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), both of which are based on fish assemblage data, and the Invertebrate Community Index (ICI), which is based on macroinvertebrate assemblage data. Criteria for each index are specified for each of Ohio's five ecoregions (as described by Omernik 1988), and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the existing chemical and whole effluent toxicity evaluation methods and criteria, figure prominently in the monitoring and assessment of Ohio's surface water resources.

The following documents support the use of biological criteria by outlining the rationale for using biological information, the methods by which the biocriteria were derived and calculated, the field methods by which sampling must be conducted, and the process for evaluating results:

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

___ 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

___ 1989b. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecological Assessment Section, Columbus, Ohio.

___ 1989c. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Quality Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

___ 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

___ 2008a. 2008 Updates to Biological criteria for the protection of aquatic life: Volume II and Volume II Addendum. Users manual for biological field assessment of Ohio surface waters. Div. of Surface Water, Ecol. Assess. Sect., Groveport, Ohio.

___ 2008b. 2008 Updates to Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. of Surface Water, Ecol. Assess. Sect., Groveport, Ohio.

___ 2006a. Methods for assessing habitat in flowing waters: Using the Qualitative Habitat Evaluation Index (QHEI). Ohio EPA Tech. Bull. EAS/2006-06-1. Revised by the Midwest Biodiversity Institute for Div. of Surface Water, Ecol. Assess. Sect., Groveport, Ohio.

_____. 2006b. 2006 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Since the publication of the preceding guidance documents, the following new publications by the Ohio EPA have become available. These publications should also be consulted as they represent the latest information and analyses used by the Ohio EPA to implement the biological criteria.

DeShon, J.D. 1995. Development and application of the invertebrate community index (ICI), pp. 217-243. in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995a. Biological criteria program development and implementation in Ohio, pp. 109-144. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995b. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. 1995c. Policy issues and management applications for biological criteria, pp. 327-344. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995d. The role of biological criteria in water quality monitoring, assessment, and regulation. Environmental Regulation in Ohio: How to Cope With the Regulatory Jungle. Inst. of Business Law, Santa Monica, CA. 54 pp.

Yoder, C.O. and M.A. Smith. 1999. Using fish assemblages in a State biological assessment and criteria program: essential concepts and considerations, pp. 17-63. in

T. Simon (ed.). Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton, FL.

These documents and this report may be obtained by writing to:

Ohio EPA, Division of Surface Water

Ecological Assessment Section

4675 Homer Ohio Lane

Groveport, Ohio 43125

(614) 836-8777

FOREWORD

What is a Biological and Water Quality Survey?

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year the Ohio EPA conducts biosurveys in 4-5 watersheds study areas with an aggregate total of 250-300 sampling sites.

The Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by the Ohio EPA (*e.g.,* NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1], Water Quality Permit Support Documents [WQPSDs]), and are eventually incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]).

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators consisting of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach includes a hierarchical continuum from administrative to true environmental indicators (Figure 1). The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4)

changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health, ecology, or other effects (ecological condition, pathogens). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental "results" (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

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

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data,

effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Integrated Report, the Ohio Nonpoint Source Assessment, and other technical bulletins.

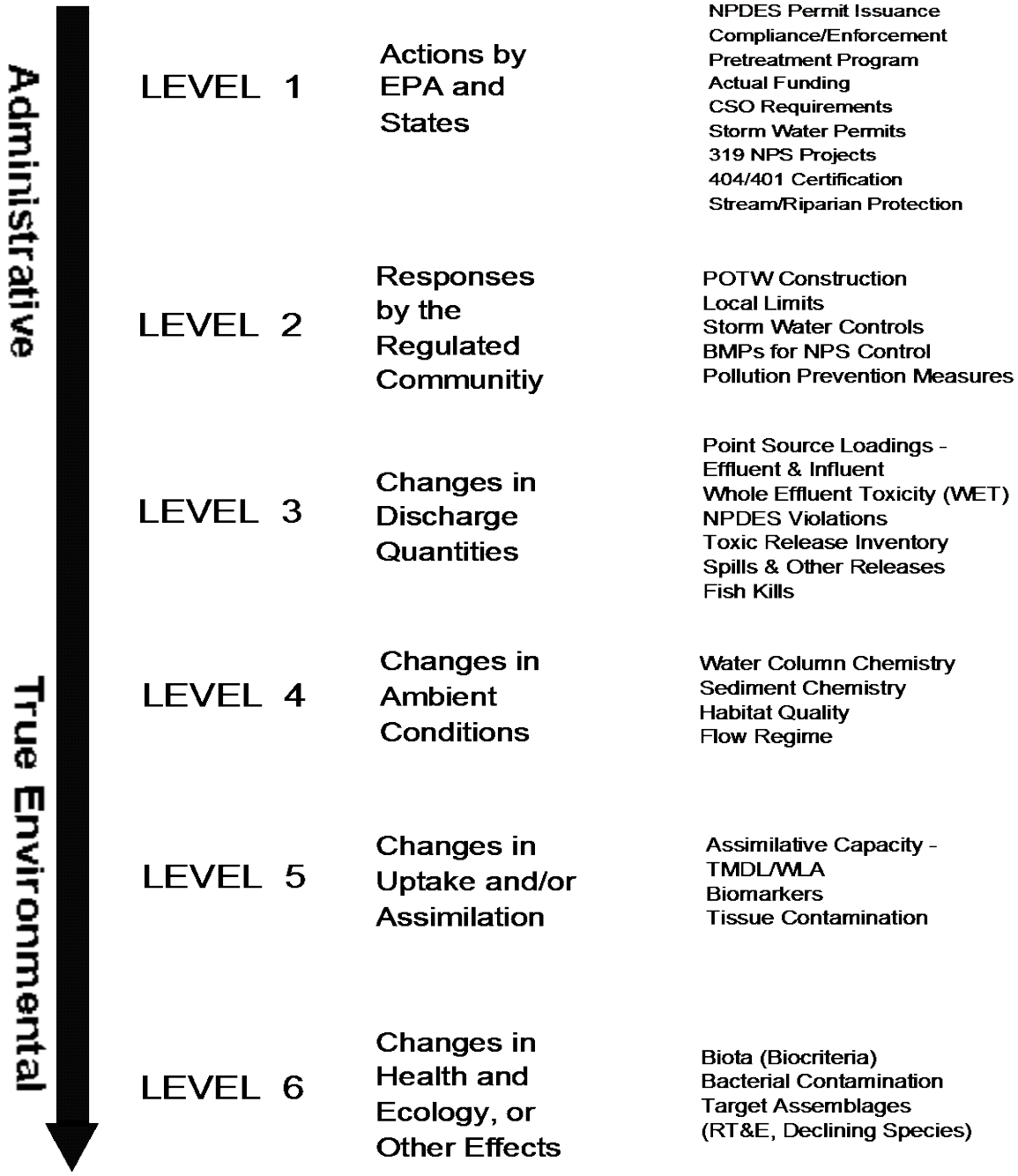

Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by the U.S. EPA.

Ohio Water Quality Standards: Designated Aquatic Life Use

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

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

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

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

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned by state or federal law;* the representative

aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 mi^2 drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.,* true ephemeral streams), or other irretrievably altered waterways.

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

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use can be having a water depth of at least one meter over an area of at least 100 square feet or, lacking this, where frequent human contact is a reasonable expectation. If a water body does not meet either criterion, the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.,* fecal coliform, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Attainment of recreation uses are evaluated based on monitored bacteria levels. The Ohio Water Quality Standards state that all waters should be free from any public health nuisance associated with raw or poorly treated sewage (Administrative Code 3745-1-04,

Part F). Additional criteria (Administrative Code 3745-1-07) apply to waters that are designated as suitable for full body contact such as swimming (PCR) or for partial body contact such as wading (SCR). These standards were developed to protect human health, because even though fecal coliform bacteria are relatively harmless in most cases, their presence indicates that the water has been contaminated with fecal matter.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health.

MECHANISMS FOR WATER QUALITY IMPAIRMENT

The following paragraphs are provided to present the varied causes of impairment that affect the resource quality of lotic systems in Ohio. While the various perturbations are presented under separate headings, it is important to remember that they are often interrelated and cumulative in terms of the detrimental impact that can result.

Habitat and Flow Alterations

Habitat alteration, such as channelization, negatively impacts biological communities directly by limiting the complexity of living spaces available to aquatic organisms. Consequently, fish and macroinvertebrate communities are not as diverse. Indirect impacts include the removal of riparian trees and field tiling to facilitate drainage. Following a rain event, most of the water is quickly removed from tiled fields rather than filtering through the soil, recharging ground water, and reaching the stream at a lower volume and more sustained rate. As a result, small streams more frequently go dry or become intermittent. Urbanization impacts include removal of riparian trees, influx of

stormwater runoff, straightening and piping of stream channels, and riparian vegetation removal.

Tree shade is important because it limits the energy input from the sun, moderates water temperature, and limits evaporation. Removal of the tree canopy further degrades conditions because it eliminates an important source of coarse organic matter essential for a balanced ecosystem. Riparian vegetation aids in nutrient uptake, may decrease runoff rate into streams, and helps keep soil in place. Erosion impacts channelized streams more severely due to the lack of a riparian buffer zone to slow runoff, trap sediment and stabilize banks. Additionally, deep trapezoidal channels lack a functioning flood plain and therefore cannot expel sediment as would occur during flood events along natural watercourses. The confinement of flow within an artificially deep channel accelerates the movement of water downstream, exacerbating flooding of neighboring properties.

The lack of water movement under low flow conditions can exacerbate impacts from organic loading and nutrient enrichment by limiting re-aeration of the stream. The amount of oxygen soluble in water decreases as temperature increases. This is one reason why tree shade is so important. The two main sources of oxygen in water are diffusion from the atmosphere and plant photosynthesis. Turbulence at the water surface is critical because it increases surface area and promotes diffusion, but channelization eliminates turbulence produced by riffles, meanders, and debris snags. Plant photosynthesis produces oxygen, but at night, respiration reverses the process and consumes oxygen. Conversely, oxygen concentrations can become supersaturated during the day, due to abnormally high amounts of photosynthesis, causing gas bubble stress to both fish and invertebrate communities. Oxygen is also used by bacteria that decay dead organic matter. Nutrient enrichment can promote the growth of nuisance algae that subsequently dies and serves as food for bacteria. Under these conditions, oxygen can be depleted unless it is replenished from the air.

Siltation and Sedimentation

Whenever the natural flow regime is altered to facilitate drainage, increased amounts of sediment are likely to enter streams either by overland transport or increased bank erosion. The removal of wooded riparian areas furthers the erosion process. Channelization keeps all but the highest flow events confined within the artificially high banks. As a result, areas that were formerly flood plains and allowed for the removal of

sediment from the primary stream channel no longer serve this function. As water levels fall following a rain event, interstitial spaces between larger rocks fill with sand and silt and the diversity of available habitat to support fish and macroinvertebrates is reduced. Silt also can clog the gills of both fish and macroinvertebrates, reduce visibility thereby excluding site feeding fish species, and smother the nests of lithophilic fishes. Lithophilic spawning fish require clean substrates with interstitial voids in which to deposit eggs. Conversely, pioneering species benefit. They are generalists and best suited for exploiting disturbed and less heterogeneous habitats. The net result is a lower diversity of aquatic species compared with a typical warmwater stream with natural habitats.

Sediment also impacts water quality, recreation, and drinking water. Nutrients absorbed to soil particles remain trapped in the watercourse. Likewise, bacteria, pathogens, and pesticides which also attach to suspended or bedload sediments become concentrated in waterways where the channel is functionally isolated from the landscape. Community drinking water systems address these issues with more costly advanced treatment technologies.

Nutrient Enrichment

The element of greatest concern is phosphorus because it is critical for plant growth and is often the limiting nutrient. The form that can be readily used by plants and therefore can stimulate nuisance algae blooms is orthophosphate (PO_4^{-3}). The amount of phosphorus tied up in the nucleic acids of food and waste is actually quite low. This organic material is eventually converted to orthophosphate by bacteria. The amount of orthophosphate contained in synthetic detergents is a great concern however. It was for this reason that the General Assembly of the State of Ohio enacted a law in 1990 to limit phosphorus content in household laundry detergents sold in the Lake Erie drainage basin to 0.5% by weight. Inputs of phosphorus originate from both point and nonpoint sources. Most of the phosphorus discharged by point sources is soluble. Another characteristic of point sources is they have a continuous impact and are human in origin, for instance, effluents from municipal sewage treatment plants. The contribution from failed on-lot septic systems can also be significant, especially if they are concentrated in a small area. The phosphorus concentration in raw waste water is generally 8-10 mg/l and after secondary treatment is generally 4-6 mg/l. Further removal requires the added cost of chemical addition. The most common methods use the addition of lime or alum to form a precipitate, so most phosphorus (80%) ends up in the sludge.

A characteristic of phosphorus discharged by nonpoint sources is that the impact is intermittent and associated with storm water runoff. Most of this phosphorus is bound tightly to soil particles and enters streams from erosion, although some comes from tile drainage. Urban storm water is more of a concern if combined sewer overflows are involved. The impact from rural storm water varies depending on land use and management practices and includes contributions from livestock feedlots and pastures and row crop agriculture. Crop fertilizer includes granular inorganic types and organic types such as manure or sewage sludge. Pasture land is especially a concern if the livestock have access to the stream. Large feedlots with manure storage lagoons create the potential for overflows and accidental spills. Land management is an issue because erosion is worse on streams without any riparian buffer zone to trap runoff. The impact is worse in streams that are channelized because they no longer have a functioning flood plain and cannot expel sediment during flooding. Oxygen levels must also be considered, because phosphorus is released from sediment at higher rates under anoxic conditions.

There is no numerical phosphorus criterion established in the Ohio Water Quality Standards, but there is a narrative criterion that states phosphorus should be limited to the extent necessary to prevent nuisance growths of algae and weeds (Administrative Code, 3745-1-04, Part E). Phosphorus loadings from large volume point source dischargers in the Lake Erie drainage basin are regulated by NPDES permit limits. The permit limit is a concentration of 1.0 mg/l in final effluent. Research conducted by the Ohio EPA indicates that a significant correlation exists between phosphorus and the health of aquatic communities (Miltner and Rankin, 1998). It was concluded that biological community performance in headwater and wadeable streams was highest where phosphorus concentrations were lowest. It was also determined that the lowest phosphorus concentrations were associated with the highest quality habitats, supporting the notion that habitat is a critical component of stream function. The report recommends WWH biocriteria of 0.08 mg/l in headwater streams (<20 mi^2 watershed size), 0.10 mg/l in wadeable streams (>20-200 mi^2) and 0.17 mg/l in small rivers (>200-1000 mi^2).

Organic Enrichment and Low Dissolved Oxygen

The amount of oxygen soluble in water is low and it decreases as temperature increases. This is one reason why tree shade is so important. The two main sources of oxygen in water are diffusion from the atmosphere and plant photosynthesis. Turbulence at the water surface is critical because it increases surface area and promotes diffusion. Drainage practices such as channelization eliminate turbulence produced by riffles, meanders, and debris snags. Although plant photosynthesis produces oxygen by day, it is consumed by the reverse process of respiration at night. Oxygen is also consumed by bacteria that decay organic matter, so it can be easily depleted unless it is replenished from the air. Sources of organic matter include poorly treated waste water, sewage bypasses, and dead plants and algae. Dissolved oxygen criteria are established in the Ohio Water Quality Standards to protect aquatic life. The minimum and average limits are tiered values and linked to use designations (Administrative Code 3745-1-07, Table 7-1).

Ammonia

Ammonia enters streams as a component of fertilizer and manure run-off and wastewater effluent. Ammonia gas (NH_3) readily dissolves in water to form the compound ammonium hydroxide (NH_4OH). In aquatic ecosystems an equilibrium is established as ammonia shifts from a gas to undissociated ammonium hydroxide to the dissociated ammonium ion (NH_4^{+1}). Under normal conditions (neutral pH 7 and 25 □C) almost none of the total ammonia is present as gas, only 0.55% is present as ammonium hydroxide, and the rest is ammonium ion. Alkaline pH shifts the equation toward gaseous ammonia production, so the amount of ammonium hydroxide increases. This is important because while the ammonium ion is almost harmless to aquatic life, ammonium hydroxide is very toxic and can reduce growth and reproduction or cause mortality.

The concentration of ammonia in raw sewage is high, sometimes as much as 20-30 mg/l. Treatment to remove ammonia involves gaseous stripping to the atmosphere, biological nitrification and de-nitrification, and assimilation into plant and animal biomass. The nitrification process requires a long detention time and aerobic conditions like that provided in extended aeration treatment plants. Under these conditions, bacteria first convert ammonia to nitrite (*Nitrosomonas*) and then to nitrate (*Nitrobacter*).

Nitrate can then be reduced by the de-nitrification process (*Pseudomonas*) and nitrogen gas and carbon dioxide are produced as by-products.

Ammonia criteria are established in the Ohio Water Quality Standards to protect aquatic life. The maximum and average limits are tiered values based on sample pH and temperature and linked to use designations (Administrative Code 3745-1-07, Tables 7-2 through 7-8).

Metals

Metals can be toxic to aquatic life and hazardous to human health. Although they are naturally occurring elements many are extensively used in manufacturing and are byproducts of human activity. Certain metals like copper and zinc are essential in the human diet, but excessive levels are usually detrimental. Lead and mercury are of particular concern because they often trigger fish consumption advisories. Mercury is used in the production of chlorine gas and caustic soda and in the manufacture of batteries and fluorescent light bulbs. In the environment it forms inorganic salts, but bacteria convert these to methyl-mercury and this organic form builds up in the tissues of fish. Extended exposure can damage the brain, kidneys, and developing fetus. The Ohio Department of Health (ODH) issued a statewide fish consumption advisory in 1997 advising women of child bearing age and children six and under not to eat more than one meal per week of any species of fish from waters of the state because of mercury. Lead is used in batteries, pipes, and paints and is emitted from burning fossil fuels. It affects the central nervous system and damages the kidneys and reproductive system. Copper is mined extensively and used to manufacture wire, sheet metal, and pipes. Ingesting large amounts can cause liver and kidney damage. Zinc is a by-product of mining, steel production, and coal burning and used in alloys such as brass and bronze. Ingesting large amounts can cause stomach cramps, nausea, and vomiting.

Metals criteria are established in the Ohio Water Quality Standards to protect human health, wildlife, and aquatic life. Three levels of aquatic life standards are established (Administrative Code 3745-1-07, Table 7-1) and limits for some elements are based on water hardness (Administrative Code 3745-1-07, Table 7-9). Human health and wildlife standards are linked to either the Lake Erie (Administrative Code 3745-1-33, Table 33-2) or Ohio River (Administrative Code 3745-1-34, Table 34-1) drainage basins. The drainage basins also have limits for additional elements not established elsewhere that are identified as Tier I and Tier II values.

Bacteria

High concentrations of either fecal coliform bacteria or Escherichia coli (E. coli) in a lake or stream may indicate contamination with human pathogens. People can be exposed to contaminated water while wading, swimming, and fishing. Fecal coliform bacteria are relatively harmless in most cases, but their presence indicates that the water has been contaminated with feces from a warm-blooded animal. Although intestinal organisms

eventually die off outside the body, some will remain virulent for a period of time and may be dangerous sources of infection. This is especially a problem if the feces contained pathogens or disease producing bacteria and viruses. Reactions to exposure can range from an isolated illness such as skin rash, sore throat, or ear infection to a more serious wide spread epidemic. Some types of bacteria that are a concern include *Escherichia*, which cause diarrhea and urinary tract infections, *Salmonella*, which cause typhoid fever and gastroenteritis (food poisoning), and *Shigella*, which cause severe gastroenteritis or bacterial dysentery. Some types of viruses that are a concern include polio, hepatitis A, and encephalitis. Disease causing microorganisms such as cryptosporidium and giardia are also a concern.

Since fecal coliform bacteria are associated with warm-blooded animals, there are both human and animal sources. Human sources, including effluent from sewage treatment plants or discharges by on-lot septic systems, are a more continuous problem. Bacterial contamination from combined sewer overflows are associated with wet weather events. Animal sources are usually more intermittent and are also associated with rainfall, except when domestic livestock have access to the water. Large livestock farms store manure in holding lagoons and this creates the potential for an accidental spill. Liquid manure applied as fertilizer is a runoff problem if not managed properly and it sometimes seeps into field tiles.

Bacteria criteria for the recreational use are established in the Ohio Water Quality Standards to protect human health. The maximum and average limits are tiered values and linked to use designation, but only apply during the May 1-October 15 recreation season (Administrative Code 3745-1-07, Table 7-13). The standards also state that streams must be free of any public health nuisance associated with raw or poorly treated sewage during dry weather conditions (Administrative Code 3745-1-04, Part F).

Sediment Contamination

Chemical quality of sediment is a concern because many pollutants bind strongly to soil particles and are persistent in the environment. Some of these compounds accumulate in the aquatic food chain and trigger fish consumption advisories, but others are simply a contact hazard because they cause skin cancer and tumors. The physical and chemical nature of sediment is determined by local geology, land use, and contribution from manmade sources. As some materials enter the water column they are attracted to the surface electrical charges associated with suspended silt and clay particles.

Others simply sink to the bottom due to their high specific gravity. Sediment layers form as suspended particles settle, accumulate, and combine with other organic and inorganic materials. Sediment is the most physically, chemically, and biologically reactive at the water interface because this is where it is affected by sunlight, current, wave action, and benthic organisms. Assessment of the chemical nature of this layer can be used to predict ecological impact.

The Ohio EPA evaluation of sediment chemistry results are evaluated using a dual approach, first by ranking relative concentrations based on a system developed by Ohio EPA (2005) and then by determining the potential for toxicity based on guidelines developed by MacDonald et al (2000). The Ohio EPA system was derived from samples collected at ecoregional reference sites. Specific Reference Values are site specific ecoregional based metals concentrations and are used to identify contaminated stream reaches. The MacDonald guidelines are consensus based using previously developed values. The system predicts that sediments below the threshold effect concentration (TEC) are absent of toxicity and those greater than the probable effect concentration (PEC) are toxic.

Sediment samples collected by the Ohio EPA are measured for a number of physical and chemical properties. Physical attributes included % particle size distribution (sand ≥60 µ, silt 5-59 µ, clay ≤4 µ), % solids, and % organic carbon. Most locations sampled had an abundance of sediment, and no difficulties were experienced in locating ample volumes of sediment for analysis. Fine grained sediments are deposited in flood plains of natural streams during periods of high flow. This scenario changes if the stream is impounded by a dam or channelized.

Chemical attributes included metals, volatile and semi-volatile organic compounds, pesticides, and poly-chlorinated biphenyls (PCBs).

MATERIALS and METHODS

All physical, chemical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c, 2006, 2008a, 2008b), The Qualitative Habitat Evaluation Index (QHEI): Rationale,

Methods, and Application (Rankin 1989 and 1995) for aquatic habitat assessment, and the Ohio EPA Sediment Sampling Guide and Methodologies (Ohio EPA 2001). Sampling locations are listed in Table 1.

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-15). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the IBI and MIwb, indices measuring the response of the fish community, and the ICI, which indicates the response of the macroinvertebrate community. Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (Table 2) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.,* full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and a sampling location description.

Habitat Assessment

Physical habitat was evaluated using the QHEI developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989 and 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently reflect habitat conditions which have the ability to support exceptional warmwater faunas.

Sediment and Surface Water Assessment

Fine grain sediment samples were collected in the upper 4 inches of bottom material at each location using decontaminated stainless steel scoops and excavated using nitrile

gloves. Decontamination of sediment sampling equipment followed the procedures outlined in the Ohio EPA sediment sampling guidance manual (Ohio EPA 2001). Sediment grab samples were homogenized in stainless steel pans (material for VOC analysis was not homogenized), transferred into glass jars with teflon® lined lids, placed on ice (to maintain 4^{o}C) in a cooler, and shipped to Ohio EPA Division of Environmental Services. Sediment data is reported on a dry weight basis. Surface water samples were collected, preserved and delivered in appropriate containers to Ohio EPA Division of Environmental Services. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions, or published literature. Sediment evaluations were conducted using guidelines established in MacDonald et al. (2000) and Ohio Specific Reference Values (2003).

Recreation Use Assessment

Recreation use attainment was determined using the criteria established in OAC 3745-1-41:

1) *E. coli* is the only indicator organism used to evaluate recreation.
2) The recreation season extends from May 1 – Oct. 31.
3) Geometric mean content is computed on a seasonal basis.
4) Geometric mean content is the sole basis of use attainment status when 2 or more samples are taken.
5) Primary Contact Recreation (PCR) includes three separate categories each with specific numerical criteria: Class A – high use paddling streams, Class B – most typical streams and Class C – historically channelized streams that drain < 3.1 mi^{2}.

Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from the natural habitats. The artificial substrate collection provided quantitative data and consisted of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multihabitat composite sample was also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (e.g., riffle, run, pool, margin). Detailed discussion of macroinvertebrate field and laboratory procedures is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b, 2008b).

Fish Community Assessment

Fish were sampled using pulsed DC electrofishing methods. Fish were processed in the field, and included identifying each individual to species, counting, weighing, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory

Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b, 2008b).

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995a, 1995b, and 1995c). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem “health” compared to human patient “health” (Suter 1993), in this document we are referring to the process for evaluating biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

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Appendix G

Surface water chemistry results from the Broken Sword Creek basin, 2013.

		Stream Location:	RED RUN NEAR MOUTH @ HENRY COOPER RD.					
		River Mile:	0.42					
PARAMETER	UNITS	07/10/13	08/15/13	9/18/13	5/15/14	6/23/14		
CBOD20	mg/L	7.0	4.7					
Total Dissolved Solids	mg/L	142	712	834	372	428		
Total Suspended Solids	mg/L	28	<5	<5	272	10		
Arsenic	ug/L	<2.0						
Cadmium	ug/L	<0.20						
Chromium	ug/L	<2.0						
Copper	ug/L	4.4						
Lead	ug/L	2.0						
Nickel	ug/L	3.9						
Selenium	ug/L	<2.0						
Aluminum	ug/L	1990						
Barium	ug/L	38						
Calcium	mg/L	20						
Hardness, Total	mg/L	71						
Iron	ug/L	2530						
Magnesium	mg/L	5						
Manganese	ug/L	36						
Potassium	mg/L	4						
Sodium	mg/L	<5						
Strontium	ug/L	59						
Zinc	ug/L	10.0						
Alkalinity	mg/L		307	383	54	186		
Ammonia	mg/L		<0.050	<0.050	4.630	0.072		
COD	mg/L			<20	47	<20		
Chloride	mg/L		29	28	43	30		
Conductivity	umhos/cm			1210	415	681		
Nitrate+nitrite	mg/L		<0.10	<0.10	14.30	12.60		
Nitrite	mg/L		<0.020	<0.020	0.113	0.104		
Orthophosphate, dissolved	mg/L		0.011	0.017	1.080	0.058		
Sulfate	mg/L		252.0	331.0	24.1	79.2		
TKN	mg/L		0.56	<0.20	7.23	0.72		

Total Phosphorus	mg/L			0.027		0.015		1.480		0.069							
FIELD PARAMETERS																	
Time	hhmmss					10:18:00		11:25:00		10:42:00							
Conductivity	uS/cm					926		381.3		668							
Conductivity @ 25C	uS/cm					1173		475.3		747							
Dissolved Oxygen	mg/L					10.45		7.07		8.01							
Dissolved Oxygen	%					101.7		69.6		87.4							
pH	s.u.					8.10		6.92		7.52							
Temperature	°C					14.0		14.6		19.5							

		Stream Location:	**BRANDYWINE CREEK S OF BROKEN SWORD @ HOLMES CENTER RD.**														
		River Mile:				0.45											
PARAMETER	UNITS	07/10/13		08/15/13		9/18/13		5/15/14		6/23/14							
CBOD20	mg/L	7.3		4.7													
Total Dissolved Solids	mg/L	124		450		440		376		414							
Total Suspended Solids	mg/L	27		7		5		130		8							
Arsenic	ug/L	<2.0															
Cadmium	ug/L	<0.20															
Chromium	ug/L	<2.0															
Copper	ug/L	3.7															
Lead	ug/L	2.0															
Nickel	ug/L	3.0															
Selenium	ug/L	<2.0															
Aluminum	ug/L	1650															
Barium	ug/L	29															
Calcium	mg/L	19															
Hardness, Total	mg/L	64															
Iron	ug/L	2300															
Magnesium	mg/L	4															
Manganese	ug/L	33															
Potassium	mg/L	5															
Sodium	mg/L	<5															
Strontium	ug/L	54															
Zinc	ug/L	11.0															

Alkalinity	mg/L			241		217		102		222							
Ammonia	mg/L	<0.050		0.090		0.074		0.628		0.051							
COD	mg/L					<20		30		<20							
Chloride	mg/L	5		50		85		39		47							
Conductivity	umhos/cm					737		462		699							
Nitrate+nitrite	mg/L	2.42		0.80		<0.10		13.70		9.38							
Nitrite	mg/L	0.029		<0.020		<0.020		0.080		0.121							
Orthophosphate, dissolved	mg/L	0.231		0.062		0.138		0.259		0.041							
Sulfate	mg/L	7.2		54.5		42.7		29.6		45.8							
TKN	mg/L	0.77		0.67		0.76		2.17		0.37							
Total Phosphorus	mg/L	0.283		0.086		0.178		0.453		0.095							
FIELD PARAMETERS																	
Time	hhmmss					9:15:00		9:52:00		9:57:00							
Conductivity	uS/cm					576		422.6		708							
Conductivity @ 25C	uS/cm					717		530		781							
Dissolved Oxygen	mg/L					4.40		7.89		5.44							
Dissolved Oxygen	%					43.5		77.2		60.1							
pH	s.u.					7.67		7.16		7.67							
Temperature	°C					14.7		14.4		20.1							

		Stream Location:		**BROKEN SWORD CREEK @ LEMMERT RD**													
		River Mile:		19.13													
PARAMETER	UNITS	08/15/13		09/18/13		5/15/14		6/23/14									
CBOD20	mg/L	4.6															
Total Dissolved Solids	mg/L	414		440		282		352									
Total Suspended Solids	mg/L	<5		10		261		41									
Alkalinity	mg/L	246		289		90		166									
Ammonia	mg/L	<0.050		<0.050		1.020		0.065									
COD	mg/L			<20		26		<20									
Chloride	mg/L	31		28		30		27									
Conductivity	umhos/cm			728		367		548									
Nitrate+nitrite	mg/L	0.80		<0.10		8.01		10.40									
Nitrite	mg/L	<0.020		<0.020		0.055		0.098									
Orthophosphate, dissolved	mg/L	0.063		0.088		0.202		0.107									

Sulfate	mg/L	68.1		99.2		26.9		39.9									
TKN	mg/L	0.54		0.42		2.07		0.55									
Total Phosphorus	mg/L	0.098		0.129		0.381		0.137									
FIELD PARAMETERS																	
Time	hhmmss			9:25:00		10:09:00		10:04:00									
Conductivity	uS/cm			570		352.7		591									
Conductivity @ 25C	uS/cm			711		428.3		639									
Dissolved Oxygen	mg/L			7.26		7.31		6.71									
Dissolved Oxygen	%			71.6		73.8		75.4									
pH	s.u.			7.93		7.45		7.75									
Temperature	°C			14.6		15.8		21.0									

		Stream Location:	**BROKEN SWORD CREEK @ SCHWEMLEY RD.**														
		River Mile:				25.5											
PARAMETER	UNITS	07/10/13		08/15/13		9/18/13		5/15/14		6/23/14							
CBOD20	mg/L	7.5		4.6													
Total Dissolved Solids	mg/L	140		426		436		334		386							
Total Suspended Solids	mg/L	30		<5		<5		152		34							
Arsenic	ug/L	<2.0															
Cadmium	ug/L	<0.20															
Chromium	ug/L	<2.0															
Copper	ug/L	3.5															
Lead	ug/L	<2.0															
Nickel	ug/L	3.2															
Selenium	ug/L	<2.0															
Aluminum	ug/L	1790															
Barium	ug/L	36															
Calcium	mg/L	22															
Hardness, Total	mg/L	76															
Iron	ug/L	2640															
Magnesium	mg/L	5															
Manganese	ug/L	40															
Potassium	mg/L	5															
Sodium	mg/L	<5															

Strontium	ug/L	85													
Zinc	ug/L	10.0													
Alkalinity	mg/L			264		286		79		201					
Ammonia	mg/L	<0.050		<0.050		<0.050		1.570		<0.050					
COD	mg/L					141		32		<20					
Chloride	mg/L	6		32		27		35		29					
Conductivity	umhos/cm					718		376		627					
Nitrate+nitrite	mg/L	3.14		0.37		<0.10		9.98		8.81					
Nitrite	mg/L	0.024		<0.020		<0.020		0.060		0.078					
Orthophosphate, dissolved	mg/L	0.209		0.029		0.018		0.473		0.056					
Sulfate	mg/L	7.1		84.5		102.0		21.7		54.2					
TKN	mg/L	0.70		0.54		0.46		2.78		0.60					
Total Phosphorus	mg/L	0.253		0.048		0.034		0.582		0.095					
FIELD PARAMETERS															
Time	hhmmss					9:44:00		10:31:00		10:20:00					
Conductivity	uS/cm					578		346.8		644					
Conductivity @ 25C	uS/cm					703		431.4		710					
Dissolved Oxygen	mg/L					7.57		7.37		7.80					
Dissolved Oxygen	%					76.4		72.8		86.2					
pH	s.u.					7.96		7.13		7.80					
Temperature	°C					15.7		14.7		20.2					

		Stream Location:	**BROKEN SWORD CREEK @ RIDGETON-ANNAPOLIS RD. (CO. RD. 78)**												
		River Mile:				27.96									
PARAMETER	UNITS	07/10/13		08/15/13		9/18/13		5/15/14		6/23/14					
CBOD20	mg/L	7.5		5.2											
Total Dissolved Solids	mg/L	166		462		474		322		396					
Total Suspended Solids	mg/L	22		5		7		264		15					
Arsenic	ug/L	<2.0													
Cadmium	ug/L	<0.20													
Chromium	ug/L	<2.0													
Copper	ug/L	3.6													
Lead	ug/L	<2.0													
Nickel	ug/L	3.3													

Selenium	ug/L	<2.0													
Aluminum	ug/L	1380													
Barium	ug/L	39													
Calcium	mg/L	30													
Hardness, Total	mg/L	100													
Iron	ug/L	1970													
Magnesium	mg/L	6													
Manganese	ug/L	35													
Potassium	mg/L	5													
Sodium	mg/L	<5													
Strontium	ug/L	116													
Zinc	ug/L	<10													
Alkalinity	mg/L			280		295		76		208					
Ammonia	mg/L	<0.050		<0.050		<0.050		2.040		<0.050					
COD	mg/L					141		31		<20					
Chloride	mg/L	8		31		29		36		30					
Conductivity	umhos/cm					769		384		638					
Nitrate+nitrite	mg/L	4.16		0.43		<0.10		11.10		8.61					
Nitrite	mg/L	0.026		<0.020		<0.020		0.064		0.074					
Orthophosphate, dissolved	mg/L	0.172		0.015		0.015		0.461		0.043					
Sulfate	mg/L	6.3		94.2		112.0		20.4		56.1					
TKN	mg/L	0.71		0.47		<0.20		3.27		0.67					
Total Phosphorus	mg/L	0.188		0.030		0.022		0.599		0.065					
FIELD PARAMETERS															
Time	hhmmss					10:07:00		10:57:00		10:36:00					
Conductivity	uS/cm					600		357.3		654					
Conductivity @ 25C	uS/cm					748		442.7		718					
Dissolved Oxygen	mg/L					7.83		7.38		8.08					
Dissolved Oxygen	%					77.2		73.1		89.6					
pH	s.u.					7.92		7.20		7.78					
Temperature	°C					14.6		14.9		20.3					

Stream Location:	**BROKEN SWORD CREEK @ BECK RD.**
River Mile:	30.31

PARAMETER	UNITS	07/10/13		08/15/13		9/18/13		5/15/14		6/23/14					
CBOD20	mg/L	6.4		5.0											
Total Dissolved Solids	mg/L	196		410		410		274		368					
Total Suspended Solids	mg/L	26		17		<5		154		22					
Arsenic	ug/L	<2.0													
Cadmium	ug/L	<0.20													
Chromium	ug/L	<2.0													
Copper	ug/L	2.7													
Lead	ug/L	<2.0													
Nickel	ug/L	3.0													
Selenium	ug/L	<2.0													
Aluminum	ug/L	1190													
Barium	ug/L	42													
Calcium	mg/L	40													
Hardness, Total	mg/L	133													
Iron	ug/L	1790													
Magnesium	mg/L	8													
Manganese	ug/L	37													
Potassium	mg/L	4													
Sodium	mg/L	<5													
Strontium	ug/L	173													
Zinc	ug/L	<10													
Alkalinity	mg/L			263		302		86		228					
Ammonia	mg/L	<0.050		<0.050		<0.050		1.360		<0.050					
COD	mg/L					<20		24		<20					
Chloride	mg/L	8		21		27		21		25					
Conductivity	umhos/cm					688		335		615					
Nitrate+nitrite	mg/L	4.87		0.28		<0.10		9.08		6.04					
Nitrite	mg/L	0.023		<0.020		<0.020		0.044		0.042					
Orthophosphate, dissolved	mg/L	0.104		0.010		<0.010		0.222		0.014					
Sulfate	mg/L	<5.0		71.9		64.7		16.7		46.1					
TKN	mg/L	0.76		0.48		0.41		2.35		0.72					
Total Phosphorus	mg/L	0.125		0.072		0.032		0.345		0.018					
FIELD PARAMETERS															

Time	hhmmss					10:32:00		11:19:00		10:53:00					
Conductivity	uS/cm					546		326.4		622					
Conductivity @ 25C	uS/cm					678		400.3		697					
Dissolved Oxygen	mg/L					7.03		7.47		8.22					
Dissolved Oxygen	%					69.6		74.7		89.5					
pH	s.u.					7.85		7.29		7.66					
Temperature	°C					14.8		15.3		19.4					

		Stream Location:	**TRIB. TO BROKEN SWORD CREEK (28.04) @ CO. RD. 78**												
		River Mile:	0.77												
PARAMETER	UNITS	07/10/13		08/15/13		9/18/13		5/15/14		6/23/14					
CBOD20	mg/L	6.6		4.4											
Total Dissolved Solids	mg/L	220		448		456		330		424					
Total Suspended Solids	mg/L	42		8		8		159		<5					
Arsenic	ug/L	<2.0													
Cadmium	ug/L	<0.20													
Chromium	ug/L	<2.0													
Copper	ug/L	4.8													
Lead	ug/L	<2.0													
Nickel	ug/L	3.8													
Selenium	ug/L	<2.0													
Aluminum	ug/L	1330													
Barium	ug/L	52													
Calcium	mg/L	44													
Hardness, Total	mg/L	147													
Iron	ug/L	2190													
Magnesium	mg/L	9													
Manganese	ug/L	59													
Potassium	mg/L	5													
Sodium	mg/L	6													
Strontium	ug/L	147													
Zinc	ug/L	10.0													
Alkalinity	mg/L			287		358		84		243					
Ammonia	mg/L	0.059		0.059		<0.050		1.820		<0.050					

COD	mg/L					<20		34		<20					
Chloride	mg/L	13		42		48		43		60					
Conductivity	umhos/cm					782		416		721					
Nitrate+nitrite	mg/L	5.79		2.47		0.79		9.84		7.06					
Nitrite	mg/L	0.028		0.067		0.024		0.080		0.110					
Orthophosphate, dissolved	mg/L	0.324		0.117		0.209		0.642		0.115					
Sulfate	mg/L	5.2		50.8		37.2		17.0		37.3					
TKN	mg/L	0.92		0.53		0.39		4.84		0.36					
Total Phosphorus	mg/L	0.369		0.138		0.234		0.792		0.101					
FIELD PARAMETERS															
Time	hhmmss					9:57:00		10:46:00		11:08:00					
Conductivity	uS/cm					601		376.8		715					
Conductivity @ 25C	uS/cm					764		468.8		789					
Dissolved Oxygen	mg/L					7.15		7.65		8.15					
Dissolved Oxygen	%					69.2		75.5		90					
pH	s.u.					7.89		7.15		8.00					
Temperature	°C					13.8		14.7		20.1					

Appendix H

Fish kill results from the Broken Sword Creek basin, 2013.

RECEIVED
SEP 12 2013
OHIO E.P.A.
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LAW ENFORCEMENT AUG -5 2013 DISTRICT TWO

LIDR 02-14-17-129

Parr

DIVISION OF WILDLIFE
Ohio Department of Natural Resources
POLLUTION, INITIAL REPORT

Form 231/DNR 9062
(R404)

Name of waters	Watershed	Township	County
Broken Sword Creek	Sandusky River	Liberty	Crawford

Notice of pollution received (date and time - method): Voice mail message on July 20, 2013 @ 19:30

Arrived at scene (date and time - method): July 21, 2013 @ 09:31

Kind of investigation (check type)
☐ stream litter ☐ no kill incident
Fish kill ☐ under $50 ☒ over $50

Number of dead animals _____ value _____

Length of stream or area of lake affected: Approximately 7 miles

Suspected pollution source (name, address, and phone number of operation, person, municipality, etc.,)
Unknown Source

TYPE OF OPERATION	SUSPECTED KIND OF POLLUTANT
☐ Agribusiness (Elevators etc.) ☐ Chemical Industries ☐ Farm & Feedlots ☐ Food & Kindred ☐ Government ☐ Industrial (mfg., metals, etc.) ☐ Mining & Minerals ☐ Municipal Water & Sewage ☐ Paper Products ☐ Petroleum (wells, storage, etc.) ☐ Refuse Disposal ☐ Pipelines ☐ Transportation (kind) _____ ☐ Utilities ☐ Other (specify) _____ ☒ Unknown	☐ Acids ☐ Chemicals ☐ Fertilizers ☐ Egg Wash ☐ Food & Food Products ☐ Leachate ☐ Manures ☐ Metals ☐ Oils & Gasoline ☐ Paper Wastes ☐ Pesticides & Poisons ☐ Sewage ☐ Silo Liquors ☐ Silts & Solids ☐ Soaps & Detergents ☐ Milk House Wash ☐ Thermal Effluents ☐ Other (specify) ☒ Unknown

Specific agent or cause if known (also give product made, handled, grown, or processed): Unknown

Total Amount: Unknown

Pollutant entered (check) ☐ Outfall ☐ Ditch ☐ Storm sewer
☐ Drainage ☐ Field tile ☐ Mine seep ☒ Other Unknown

Stage of water: ☐ High ☐ Low ☒ Average

Date and hour pollution discharge started Unknown ceased Unknown

WATER SAMPLES
Follow the water sample numbering and labeling procedure listed below.

Samples of specific pollutant labeled ☐ X ☐ Y ☐ Samples taken by other agency ☒ No samples taken by DOW

Water samples collected 100 yards or more upstream from where suspected pollutant entered are labeled
☒ No. 1 ☐ 1A (preserved sample) Water temperature here is 74 °F pH 7.0 D.O. 5-6 (ppm) Ammonia _____ (ppm)

Samples of waste before entering the water are labeled
☐ No. 2 ☐ 2A (preserved sample) Water temperature here is _____ °F pH _____ D.O. _____ (ppm) Ammonia _____ (ppm)

Samples collected at point just below where pollutant entered and mixed with water are labeled
☐ No. 3 ☐ 3A (preserved sample) Water temperature here is _____ °F pH _____ D.O. _____ (ppm) Ammonia _____ (ppm)

Samples collected downstream below point of mixing are labeled
☒ No. 4 ☐ 4A (preserved sample) Water temperature here is 76 °F pH 6.5 D.O. 4-5 (ppm) Ammonia _____ (ppm)

Species of wild animals collected and tag numbers
N/A

OTHER RESPONDING AGENCIES

Name and title of responder	Agency name	Agency address	Phone number
Mike Hall	SWCD	3111 St. Rt. 98, Bucyrus, OH 44820	419-562-8280
Date and time of arrival: 7/22/2013-Unknown Time	Action taken (if applicable): N/A		
Name and title of responder: Don Fishpaw	Agency name: SWCD	Agency address: 3111 St. Rt. 98, Bucyrus, OH 44820	Phone number: 419-562-8280
Date and time of arrival: 7/22/2013-Unknown Time	Action taken (if applicable): N/A		

☒ Investigation is open ☐ No further action ☐ Stream litter charges pending

Narrative Report

On Saturday, July 20, 2013 at 7:30 PM, I received a voice mail message from Law Enforcement Administrator, Officer Ron Ollis (#1058), reference a fish kill on the Broken Sword Creek on Connely Rd. Officer Ollis stated that there were several dead fish floating in the water at this location.

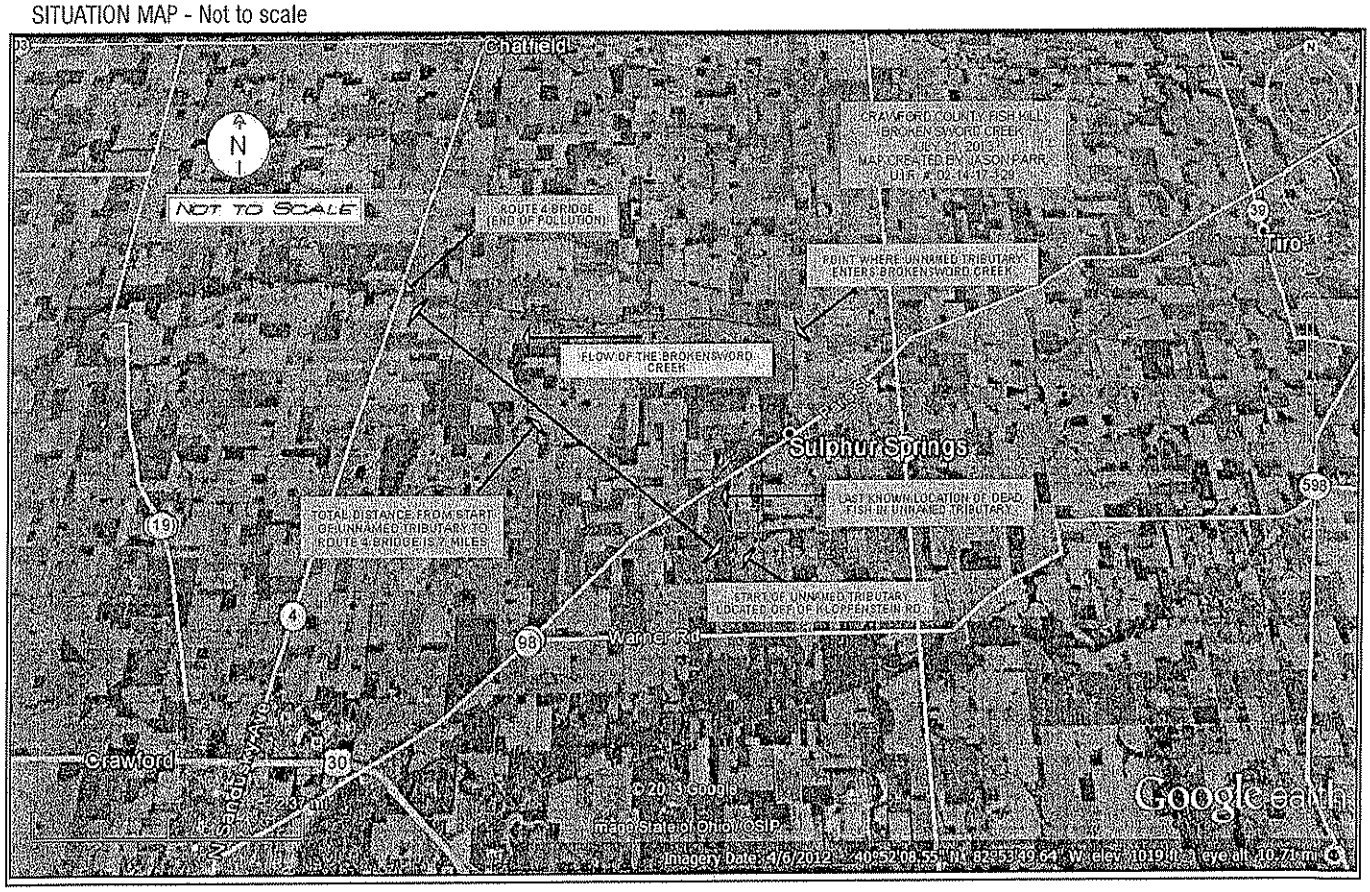
The next morning, Sunday, July 21, 2013, Officer Ollis left a second message for me. He stated that he recalled smelling a strong odor of manure the evening before (Saturday, July 20, 2013) near State Route 98 (area located south of dead fish). He mentioned that a farm on Connely Rd. (Martin Farm), south of St. Rt. 98 has had issues in the past with applying manure too heavy.

At 9:31 AM on Sunday, July 21, 2013, I arrived at the Broken Sword Creek on Connely Rd. I determined that there were dead fish from the bridge on Ridgeton-Annapolis Rd. all the way west of the Route 4 bridge. This consists of an area of approximately four miles. The next bridge west of the Route 4 bridge is on Eaton Rd. I didn't observe any dead fish at this location, however, this bridge is approximately 1.5 miles from the Route 4 bridge.

After determining the approximate size and location of the pollution, I contacted Mr. Dave Schilt from the Ohio Environmental Protection Agency to make him aware of the situation. I also contacted the Crawford County Soil and Water Conservation District and left a voice mail message describing the situation and location of the pollution.

(THIS NARRATIVE REPORT IS CONTINUED ON AN ADDITIONAL EVENTS CONTINUATION FORM).

SITUATION MAP - Not to scale



Jason M. Parr

(Signature of Officer)

07/29/2013 / 1006 hrs.

(Date and Time Completed)

DISTRIBUTION OF COPIES:

1. Wildlife Enforcement HQS Date Sent 08/05/2013

DIVISION OF WILDLIFE
Ohio Department of Natural Resources

ADDITIONAL EVENTS CONTINUATION FORM

☐ Hunter Incident ☒ Pollution ☐ Stream Litter ☐ Form 45
☐ Other

Subject: Broken Sword Creek Pollution Investigation

Officer: Jason M. Parr Date/Time: July 21, 2013/09:30-20:00

(CONTINUED FROM FORM 231)

I tested the water for the pH, dissolved oxygen and the water temperature under the State Route 602 bridge (located east of dead fish at Ridgeton-Annapolis Rd. bridge) as well as under the Ridgeton-Annapolis Rd. bridge. Those results can be found on the Form 231.

State Wildlife Officer Supervisor Kevin Russell arrived on-scene at 14:14. Upon his arrival we placed the two kayaks he brought with him on the Broken Sword Creek at the Ridgeton-Annapolis Rd. bridge. We headed east a short distance on the kayaks to determine if there were any additional dead fish that direction as well as to try to determine where the pollutant may have entered the creek. Approximately 200 yards east of the Ridgeton-Annapolis Rd. bridge we located a small unnamed tributary on the south side of the Broken Sword Creek. Within this unnamed tributary we found dead fish. Pictures were collected and Officer Russell and we began our count of dead fish.

Wildlife Officer Supervisor Kevin Russell and I kayaked the approximately four miles of the Broken Sword Creek from just east of the Ridgeton-Annapolis Rd. bridge to the State Route 4 bridge. We observed thousands of dead fish along our way. The majority of these dead fish consisted of suckers, creek chubs, minnows, sunfish and bullheads. Numerous pictures were taken by Officer Russell. I took notes on the number, species and size of dead fish we observed between the Ridgeton-Annapolis Rd. bridge to the State Route 4 bridge.

Upon finishing on the Broken Sword Creek, Officer Russell and I drove to the unnamed tributary located off of Ridgeton-Annapolis Rd. We continued to follow this small ditch to the south, observing dead fish in the ditch as we drove from one location to the next. We ended up on the south side of State Route 98, east of Connely Rd. This location is just east of a dairy farm located at 4363 State Route 98. This was the last location we found any dead fish. We traveled to where the unnamed tributary starts, located off of Klopfenstein Rd., approximately 3/4 to 1 mile directly south of the location where we observed the last dead fish. Where the ditch begins (located on Elkhorn Lake Hunt Club property) off of Klopfenstein Rd., we observed clear water and no dead fish (it is seven miles from the start of this unnamed tributary to the State Route 4 bridge over the Broken Sword Creek).

Located between the start of the unnamed tributary on Klopfenstein Rd. and the dairy farm on State Route 98, is a second dairy farm. This farm is located at 4091 Connely Rd. This dairy farm also appears to border the unnamed tributary which contained the dead fish. I believe that this farm located off of Connely Rd. is the farm that Officer Ollis referenced in his second voice mail message to me as being a farm that has had problems in the past with applying manure too heavy (Martin Farm). It is unknown at this time if either of these two dairy farms had anything to do with the pollution and fish kill. State Wildlife Officer Investigator Jeff Collingwood and I will be attempting to speak to the two dairy farmers about this incident on Tuesday, July 30, 2013.

DIVISION OF WILDLIFE
Ohio Department of Natural Resources

ADDITIONAL EVENTS CONTINUATION FORM

☐ Hunter Incident ☒ Pollution ☐ Stream Litter ☐ Form 45
☐ Other

Subject: Broken Sword Creek Pollution Investigation

Officer: Jason M. Parr Date/Time: July 21, 2013/09:30-20:00

(CONTINUATION FORM #2)

Prior to working with Wildlife Officer Investigator Collingwood on this investigation, I have the following invested in this pollution:

1) Used 2 dissolved oxygen ampules from my pollution kit as a result of this incident.
2) A total of 11 hours and 17 minutes of work hours as a result of this investigation (3 hours 17 minutes of overtime).
3) I drove a total of 127 miles as a result of this investigation.

The following is the breakdown of the species, size and numbers of dead fish observed and recorded during the investigation on Sunday, July 21, 2013:

Sunfish:	1"-2": 46	Minnows:	2,792 total	Creek Chubs:	1"-2": 24
	2"-3": 147				2"-3": 122
	3"-4": 21				3"-4": 53
	4"-5": 14				4"-5": 967
	5"-6": 18				5"-6": 267
Bullheads:	4": 163	Smallmouth Bass:	6": 1	Suckers:	4"-5": 771
	5": 171		7": 1		6": 186
	6": 15				8": 39
	7": 5				9": 9
	8": 6				12": 13
					13": 2