5 Watershed Inventory- Part III

5.1 Watershed Inventory Summary

Thirty five (35) stream sites were monitored over a one year period beginning in April 2013 by IDEM to support the development of our watershed plan and a Total Maximum Daily Load (TMDL) study. IDEM field crews collected *E. coli*, fish, macroinvertebrate, habitat, and water chemistry data to help determine if the streams were meeting their designated uses (i.e. are they swimmable and fishable). *E. coli* samples were collected to evaluate full body contact recreational use while fish and macroinvertebrate communities were assessed to evaluate aquatic life uses. Habitat and water chemistry data were collected to help identify potential biotic community stressors. Through this process, IDEM identified 210 miles of stream that do not support full body contact recreational use and 225 miles of stream that do not support aquatic life use.

5.1.1 Patterns & Trends Affecting Full Body Contact Recreational Use

Figure 206 shows the location of the stream segments that will be included on the draft 2016 303d List of Impaired Waterbodies for *E. coli* and the median site concentrations. Figure 207 summarizes *E. coli* concentrations for all sites in the watershed. It's apparent from these figures that full body contact recreational use is threatened throughout much the watershed.

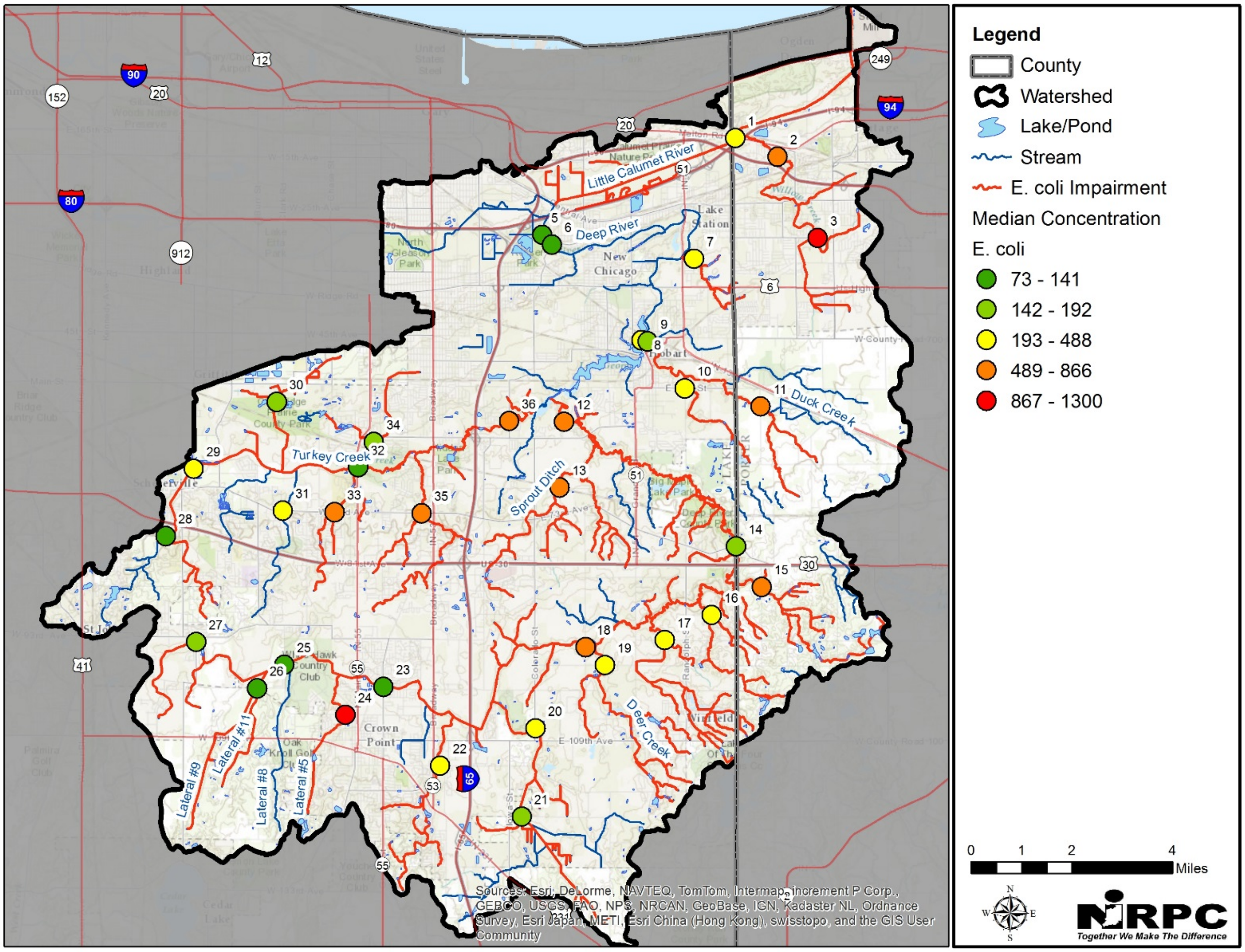


Figure 206 E. coli impaired stream reaches and sites with elevated E. coli concentrations

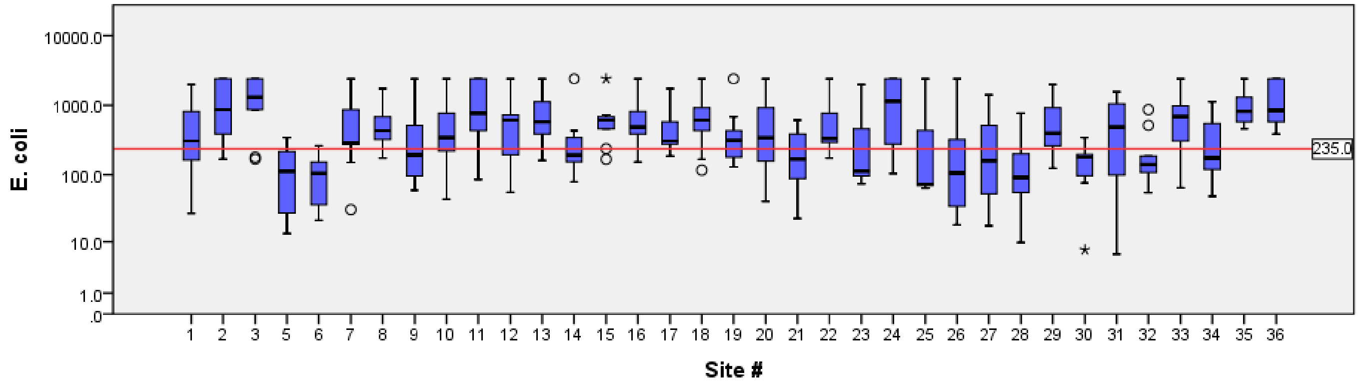


Figure 207 Box plot illustrating site E. coli concentrations within the watershed

Load duration curves for *E. coli* in the TMDL report show that many sites exceed the water quality standard across low to moderately high stream flow conditions indicating the contribution of nonpoint and at least periodic point sources. There is a strong positive correlation between *E. coli* and other water quality parameters including total solids, total dissolved solids, conductivity, and chloride (Table 83) indicating sewage as a likely source. *E. coli* is also positively correlated, although not as strongly, to riparian deciduous forest indicating wildlife sources. *E. coli* observations followed monthly/seasonal variations associated with water temperature. Median concentrations increased throughout the spring, peaking in July, before declining in the cooler fall months (Figure 208).

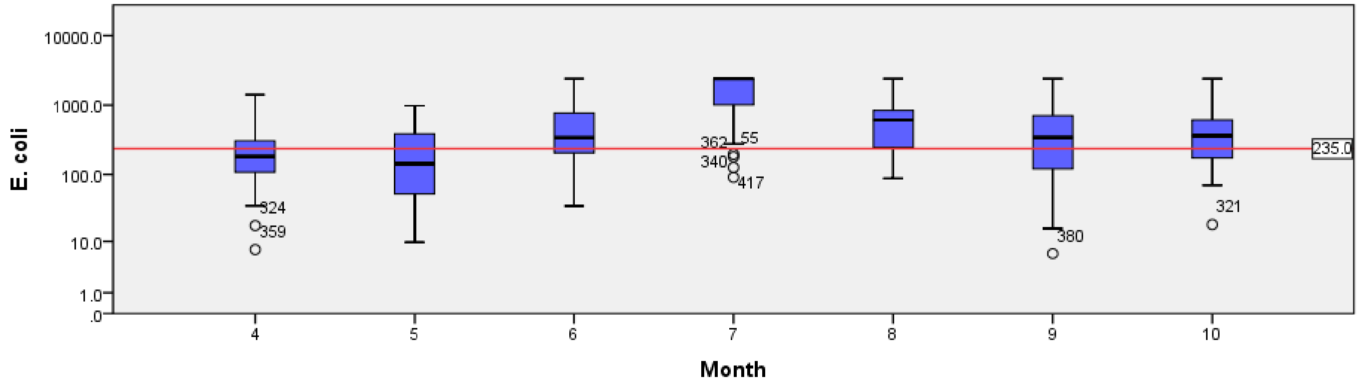


Figure 208 Box plot illustrating monthly E. coli concentrations within the watershed

5.1.2 Patterns & Trends Affecting Aquatic Life Use

Figure 209 shows the location of stream segments that will be included on the draft 2016 303d List for impaired biotic communities and stressors identified at each sampling site (i.e. failure to meet water quality and habitat targets, see Table 38). Impaired biotic communities is largely a watershed wide issue. Figure 210 summarizes dissolved oxygen, sediment and nutrient concentrations for all sites in the watershed and Figure 211 summarizes habitat data.

Since none of the streams in our watershed are designated as limited use by the State, they are required to be capable of supporting a well-balanced, warm water aquatic community whether the streams are naturally occurring or manmade systems (i.e. ditches). The water quality regulatory definition of a “well-balanced aquatic community” is “an aquatic community which is diverse in species composition, contains several different trophic levels, and is not composed mainly of strictly pollution tolerant species”. Even the best water quality monitoring sites in our watershed are characterized as lacking sensitive fish/macroinvertebrate species and having skewed trophic structures. Expected species are often absent and tolerant species dominate. The most heavily impacted reaches have few species and individuals present.

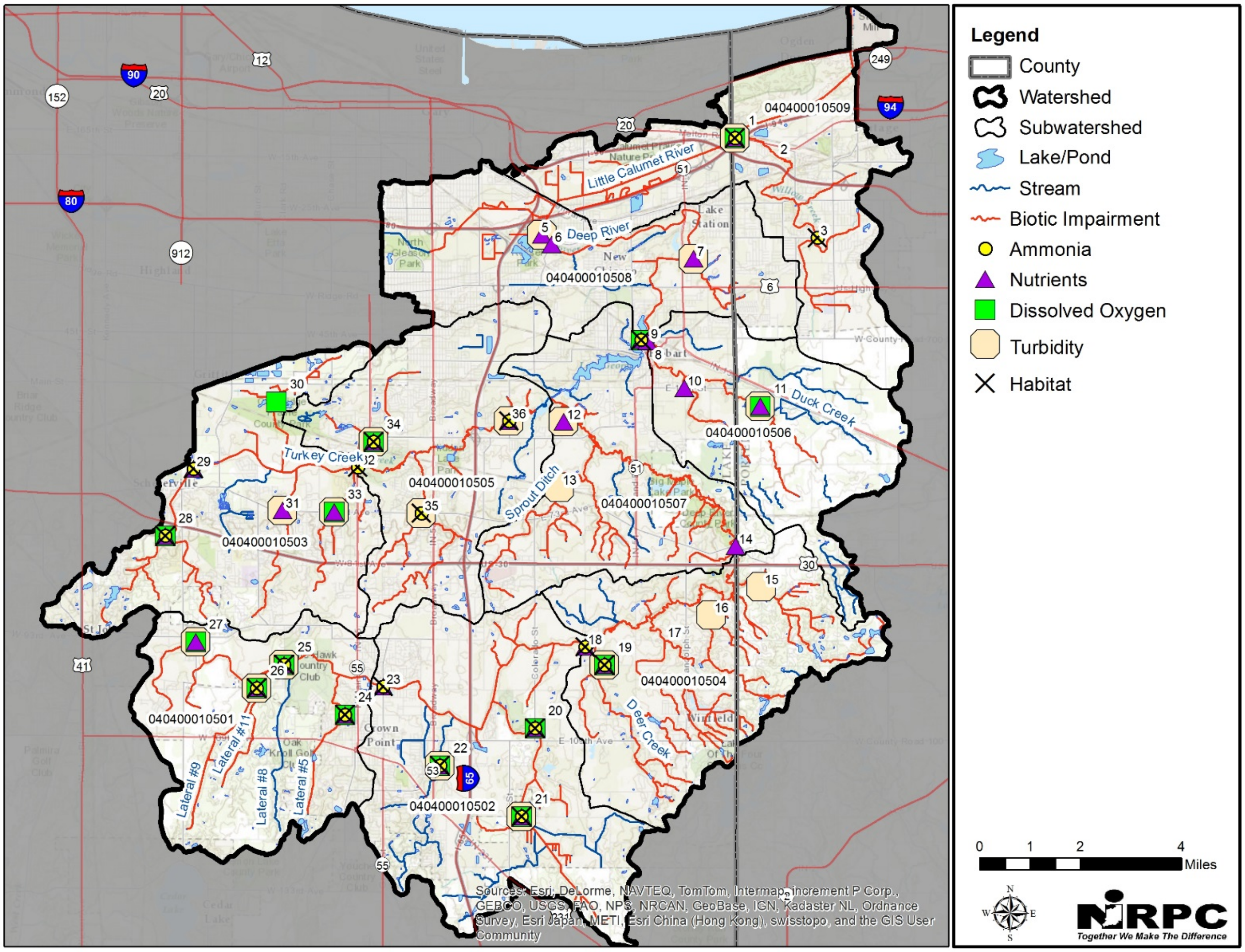
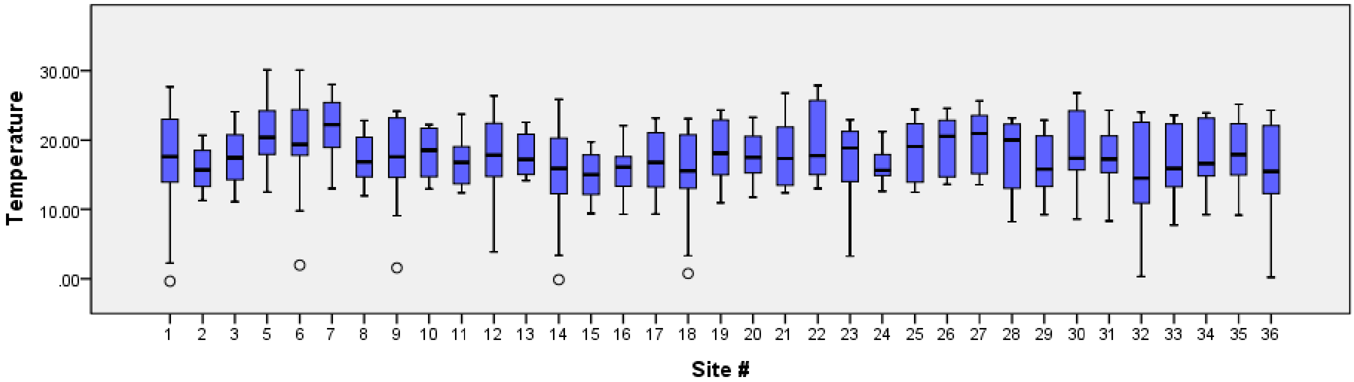
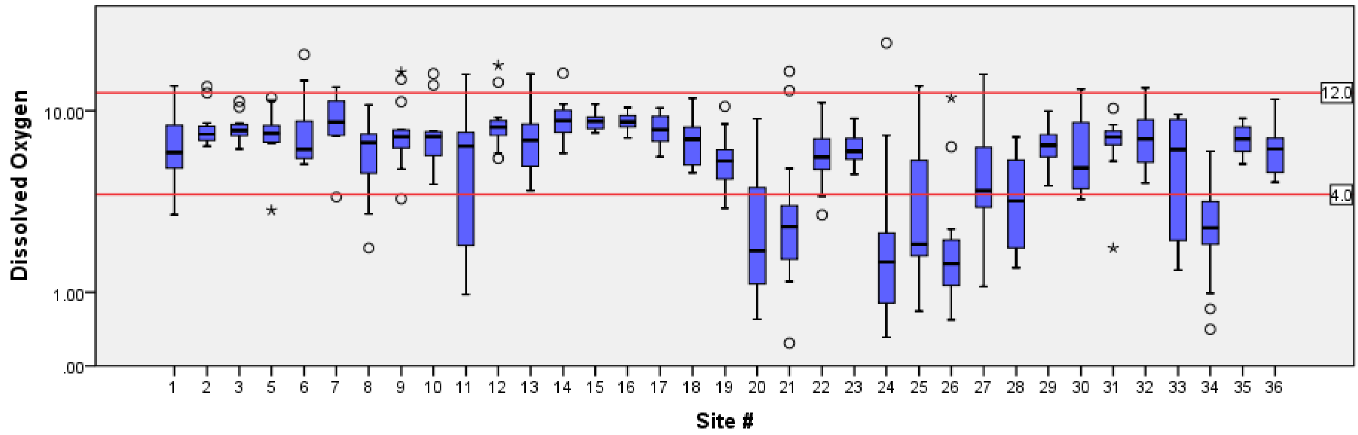
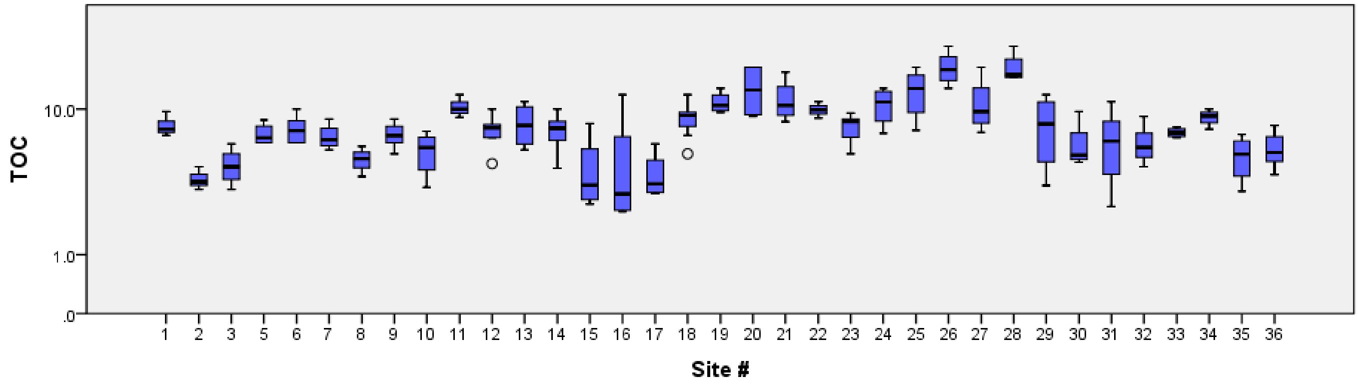
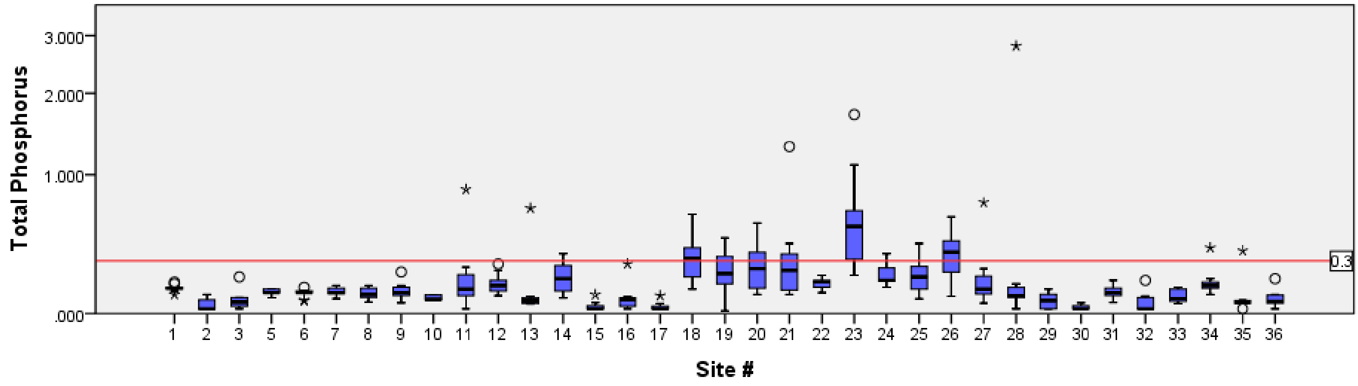


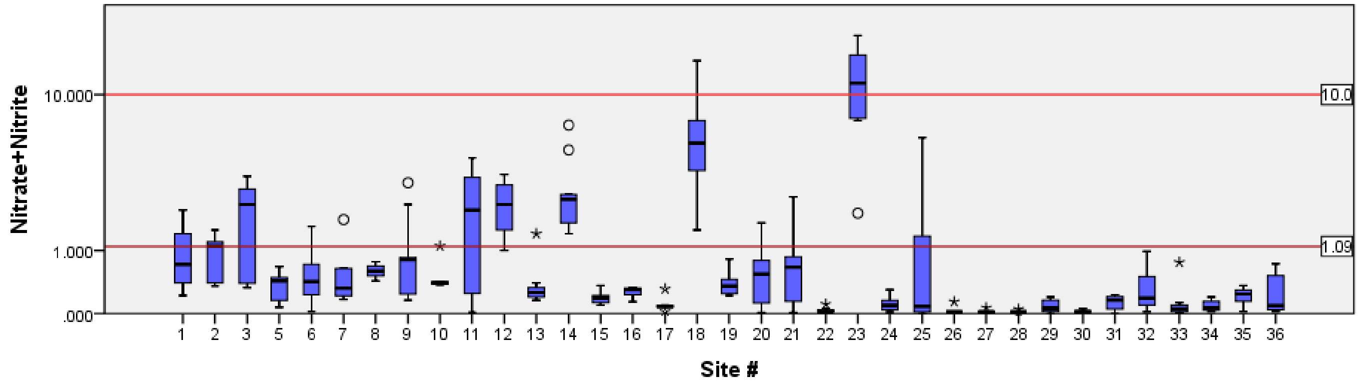
Figure 209 Biotic impairment and stressor co-occurrences




Dissolved Oxygen
10.00
1.00
.00
12.0
4.0
1 2 3 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Site #


TOC
10.0
1.0
.0
1 2 3 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Site #


Total Phosphorus
3.000
2.000
1.000
.000
0.3
1 2 3 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Site #


Nitrate+Nitrite
10.000
1.000
.000
10.0
1.09
1 2 3 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Site #

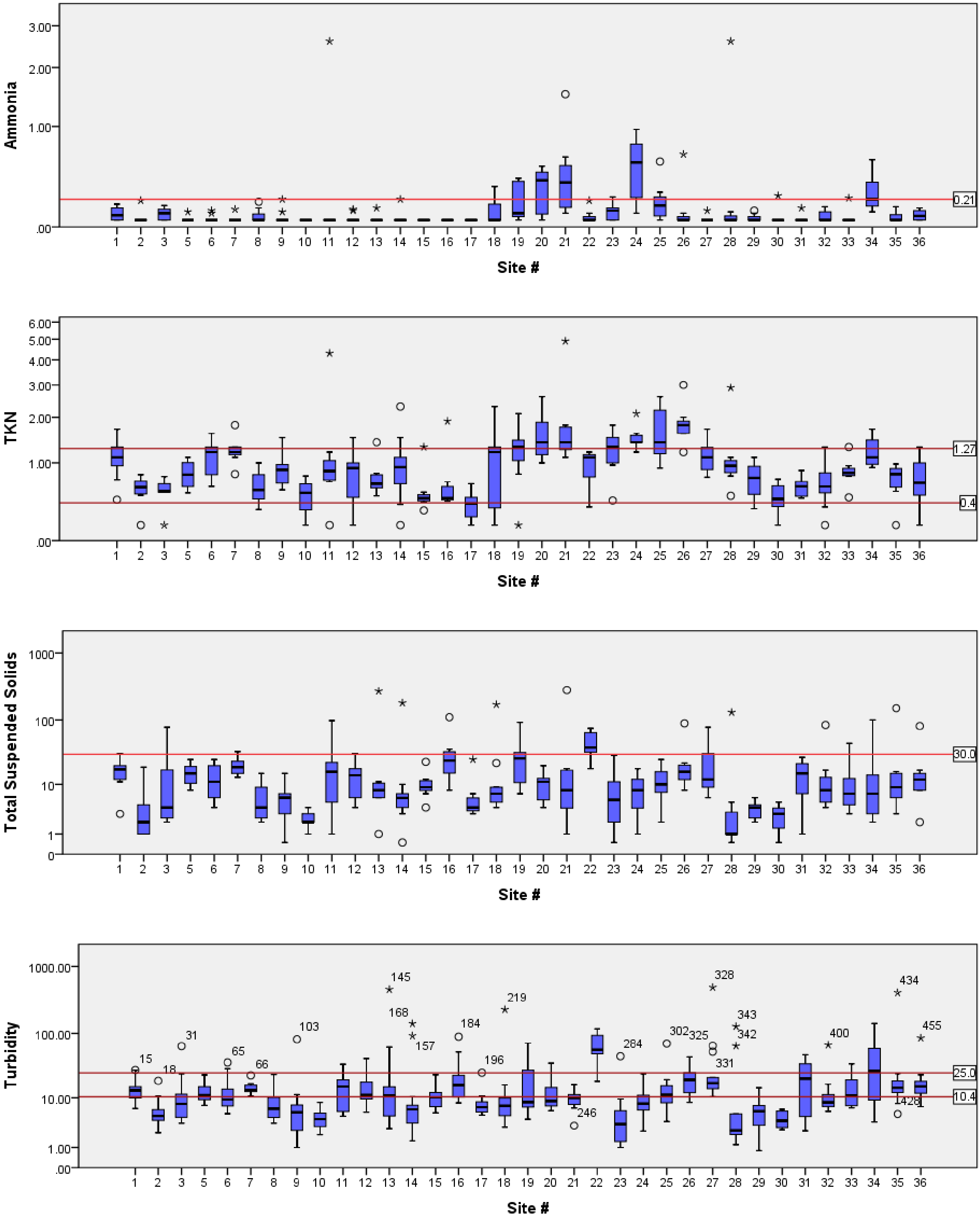


Figure 210 Box plots illustrating site temperature, dissolved oxygen, total organic carbon, sediment, and nutrient concentrations within the watershed

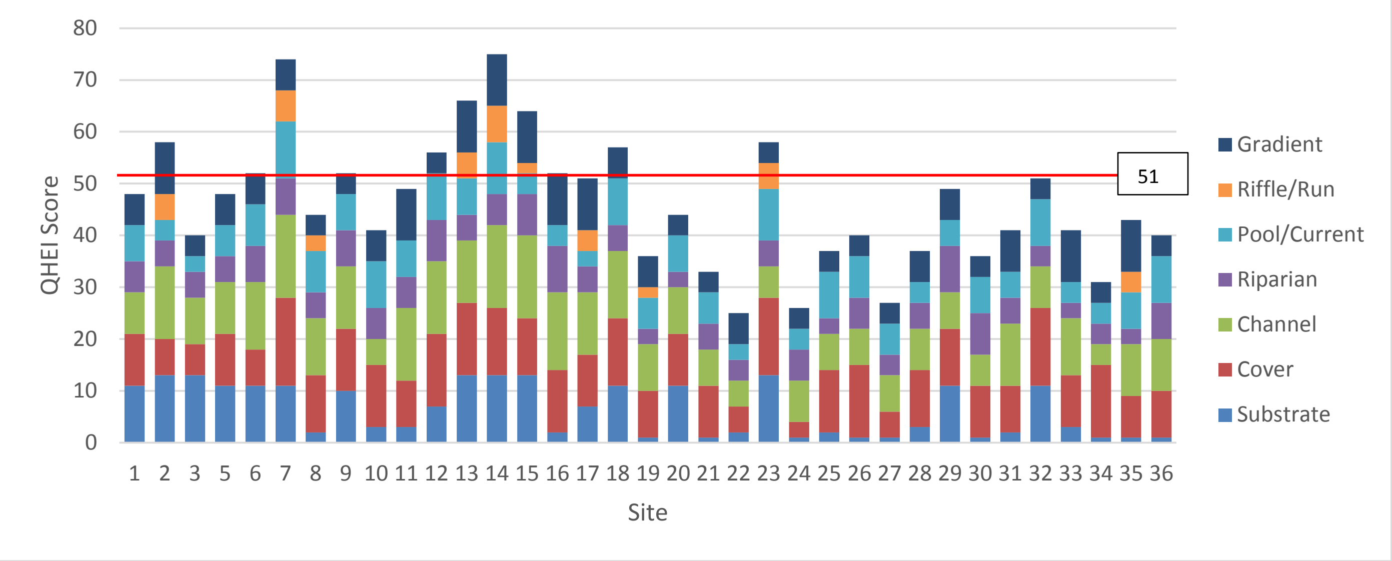


Figure 211 Site Qualitative Habitat Evaluation Index scores within the watershed

Several candidate causes (stressors) have been identified as potential contributors to the observed fish and/or benthic macroinvertebrate community impairments. These include elevated water temperatures, low dissolved oxygen levels, excess nutrient loading, ammonia toxicity, excess sediment loading, and habitat degradation. Table 82 provides a summary and initial evaluation of where the candidate causes co-occur with biotic impairments. This information is also spatially represented in Figure 209. Site 2 is the only site in which potential stressors are not readily apparent.

Low dissolved oxygen levels, excess nutrient loading, ammonia toxicity and habitat degradation are the stressors that most often co-occur with biotic impairments. The connection between water temperature and impaired biotic communities is ambiguous at this point. Additional data would be useful to explore the relationship further.

Site	Biotic Impairment		Candidate Causes/ Stressors											
			↑Temp	↓DO	↑ Nutrients			Toxicity	↑ Sediment		↓Habitat Quality			
	Fish	Macros	Temp	DO	TP	NO3	TKN	NH3	TSS	Turb	QHEI	Emb	Chan	Grad
1	Yes	No	0	0	+	0	0	0	-	+	+	+	+	0
2	Yes	Yes	0	-	-	0	0	-	-	-	-	-	-	-
3	Yes	Yes	0	-	+	0	0	0	-	0	+	-	+	+
5	Yes	No	0	-	+	-	0	-	-	+	+	+	+	0
6	No	Yes	0	-	+	-	0	-	-	0	-	+	+	0
7	Yes	Yes	0	-	+	-	0	-	-	+	-	+	-	0
8	Yes	Yes	0	0	+	-	0	0	-	0	+	+	+	0
9	Yes	Yes	0	-	+	-	0	-	-	-	+	+	+	+
10	Yes	Yes	0	-	+	-	0	-	-	-	+	+	+	0
11	Yes	Yes	0	+	+	0	0	-	-	+	+	+	-	-
12	No	Yes	0	-	+	0	0	-	-	+	-	+	-	+
13	Yes	No	0	-	-	-	0	-	-	+	-	+	+	-
14	No	No	0	-	+	0	0	-	-	-	-	-	-	-
15	Yes	Yes	0	-	-	-	-	-	-	+	-	-	-	-
16	No	Yes	0	-	+	-	-	-	0	+	-	+	-	-
17	Yes	No	0	-	-	-	-	-	-	-	+	+	+	-
18	No	No	0	-	+	0	0	0	-	-	-	+	+	0
19	Yes	Yes	0	+	+	-	+	+	0	+	+	+	+	0
20	No	No	0	+	+	-	+	+	-	0	+	+	+	+

Site	Biotic Impairment		Candidate Causes/ Stressors											
			↑Temp	↓DO	↑ Nutrients			Toxicity	↑ Sediment		↓Habitat Quality			
	Fish	Macros	Temp	DO	TP	NO3	TKN	NH3	TSS	Turb	QHEI	Emb	Chan	Grad
21	Yes	Yes	0	+	+	-	+	+	-	+	+	+	+	+
22	No	No	0	+	+	-	0	-	+	+	+	+	+	0
23	No	Yes	0	-	+	+	+	0	-	0	-	-	+	+
24	Yes	Yes	0	+	+	-	+	0	-	0	+	+	+	+
25	Yes	Yes	0	+	+	0	+	0	-	+	+	+	+	+
26	Yes	Yes	0	+	+	-	+	-	-	+	+	+	+	+
27	No	Yes	0	+	+	-	0	-	0	+	+	+	+	+
28	Yes	NA	0	+	+	-	0	-	-	-	+	+	+	0
29	No	Yes	0	-	+	-	0	-	-	-	+	+	+	0
30	Yes	Yes	0	+	-	-	-	-	-	-	+	+	+	+
31	Yes	Yes	0	-	+	-	0	-	-	+	+	+	+	-
32	No	Yes	0	-	-	-	0	0	-	0	+	+	+	+
33	Yes	Yes	0	+	+	-	0	-	-	+	+	+	+	-
34	Yes	Yes	0	+	+	-	+	+	-	+	+	+	+	+
35	Yes	Yes	0	-	-	-	0	-	-	+	+	-	+	-
36	Yes	Yes	0	-	+	-	0	0	-	+	+	+	+	+

"+" Candidate cause co-occurs with biotic impairment.
"0" Uncertain or ambiguous if the candidate cause co-occurs with biotic impairment.
"-" Candidate cause does not co-occur with biotic impairment.

Table 82 Biotic impairment and candidate cause co-occurrence scoring

In most cases, multiple stressors co-occur where biotic impairments are observed. Having multiple stressors co-occur where there are biotic impairments is not uncommon as was shown in the conceptual causal pathway diagrams included in Section 3.2. A correlation analysis was completed to explore the degree of relationships between these stressors. The results are shown below in Table 83. Red equals a statistically significant negative correlation and green a statistically significant positive correlation.

Correlation values are interpreted as follows:

- A coefficient of 0 indicates that the variables are not related.
- A negative coefficient indicates that as one variable increases, the other decreases.
- A positive coefficient indicates that as one variable increases the other also increases.
- Larger absolute values of coefficients indicate stronger associations.

		DO	DO % Sat	NH3	NO3	TKN	TP	TSS	Turb	TS	TDS	E coli	pH	Cond	Chl	TOC	COD
DO	Corr.	1.000	.981**	-.730**	.373*	-.581**	-.539**	-.146	-.179	-.294	-.055	.190	.845**	-.253	-.178	-.719**	-.632**
	Sig.	.	.000	.000	.027	.000	.001	.401	.303	.087	.753	.275	.000	.143	.305	.000	.000
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
DO % Sat	Corr.	.981**	1.000	-.762**	.347*	-.562**	-.521**	-.143	-.162	-.332	-.090	.137	.872**	-.299	-.194	-.693**	-.593**
	Sig.	.000	.	.000	.041	.000	.001	.413	.353	.051	.607	.432	.000	.081	.265	.000	.000
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
NH3	Corr.	-.730**	-.762**	1.000	.139	.637**	.612**	.174	.051	.407*	.205	-.026	-.727**	.373*	.385*	.622**	.520**
	Sig.	.000	.000	.	.426	.000	.000	.318	.773	.015	.238	.881	.000	.027	.022	.000	.001
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
NO3	Corr.	.373*	.347*	.139	1.000	.152	.216	-.067	-.211	-.052	-.019	.198	.158	.003	.101	-.090	-.054
	Sig.	.027	.041	.426	.	.384	.212	.704	.224	.767	.914	.254	.363	.986	.563	.607	.756
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TKN	Corr.	-.581**	-.562**	.637**	.152	1.000	.864**	.381*	.258	.150	.008	-.270	-.539**	.095	.161	.865**	.876**
	Sig.	.000	.000	.000	.384	.	.000	.024	.135	.389	.962	.117	.001	.587	.357	.000	.000
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TP	Corr.	-.539**	-.521**	.612**	.216	.864**	1.000	.452**	.374*	.151	-.029	-.241	-.587**	.100	.261	.852**	.873**
	Sig.	.001	.001	.000	.212	.000	.	.006	.027	.385	.867	.163	.000	.567	.131	.000	.000

		DO	DO % Sat	NH3	NO3	TKN	TP	TSS	Turb	TS	TDS	E coli	pH	Cond	Chl	TOC	COD
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TSS	Corr.	-.146	-.143	.174	-.067	.381*	.452**	1.000	.814**	.309	.201	.020	-.017	.151	.133	.388*	.486**
	Sig.	.401	.413	.318	.704	.024	.006	.	.000	.071	.247	.907	.921	.387	.445	.021	.003
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Turb	Corr.	-.179	-.162	.051	-.211	.258	.374*	.814**	1.000	.178	.050	.068	-.037	.096	.163	.354*	.425*
	Sig.	.303	.353	.773	.224	.135	.027	.000	.	.305	.774	.698	.832	.585	.349	.037	.011
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TS	Corr.	-.294	-.332	.407*	-.052	.150	.151	.309	.178	1.000	.931**	.449**	-.412*	.931**	.757**	.200	.087
	Sig.	.087	.051	.015	.767	.389	.385	.071	.305	.	.000	.007	.014	.000	.000	.249	.618
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TDS	Corr.	-.055	-.090	.205	-.019	.008	-.029	.201	.050	.931**	1.000	.469**	-.181	.899**	.680**	.017	-.065
	Sig.	.753	.607	.238	.914	.962	.867	.247	.774	.000	.	.004	.298	.000	.000	.923	.711
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
E coli	Corr.	.190	.137	-.026	.198	-.270	-.241	.020	.068	.449**	.469**	1.000	.074	.467**	.373*	-.330	-.303
	Sig.	.275	.432	.881	.254	.117	.163	.907	.698	.007	.004	.	.672	.005	.028	.053	.076
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
pH	Corr.	.845**	.872**	-.727**	.158	-.539**	-.587**	-.017	-.037	-.412*	-.181	.074	1.000	-.382*	-.369*	-.655**	-.562**
	Sig.	.000	.000	.000	.363	.001	.000	.921	.832	.014	.298	.672	.	.023	.029	.000	.000
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Cond	Corr.	-.253	-.299	.373*	.003	.095	.100	.151	.096	.931**	.899**	.467**	-.382*	1.000	.771**	.132	.018
	Sig.	.143	.081	.027	.986	.587	.567	.387	.585	.000	.000	.005	.023	.	.000	.448	.917
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Chl	Corr.	-.178	-.194	.385*	.101	.161	.261	.133	.163	.757**	.680**	.373*	-.369*	.771**	1.000	.183	.091
	Sig.	.305	.265	.022	.563	.357	.131	.445	.349	.000	.000	.028	.029	.000	.	.293	.604
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TOC	Corr.	-.719**	-.693**	.622**	-.090	.865**	.852**	.388*	.354*	.200	.017	-.330	-.655**	.132	.183	1.000	.892**
	Sig.	.000	.000	.000	.607	.000	.000	.021	.037	.249	.923	.053	.000	.448	.293	.	.000
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
COD	Corr.	-.632**	-.593**	.520**	-.054	.876**	.873**	.486**	.425*	.087	-.065	-.303	-.562**	.018	.091	.892**	1.000
	Sig.	.000	.000	.001	.756	.000	.000	.003	.011	.618	.711	.076	.000	.917	.604	.000	.
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 83 Water quality correlation analysis results

Strong negative relationships exist between dissolved oxygen (DO) and ammonia (NH3), total Kjeldahl nitrogen (TKN), total phosphorus (TP), total organic carbon (TOC), and chemical oxygen demand (COD). The breakdown of organic materials and chemical compounds, measured by TOC and COD respectively, consumes dissolved oxygen. Excess nutrient loading, measured by TKN and TP, accelerates plant and algal growth. Bacterial breakdown of dead plant material consumes oxygen. Nitrification, the conversion of ammonia to nitrate (NO3), requires oxygen. Low oxygen levels suppress this process and therefore ammonia levels build up. The correlation analysis also showed a strong positive relationship between total suspended solids (TSS) and total phosphorus and chemical oxygen demand indicating these pollutants are sediment related.

A correlation analysis was also completed to explore the degree of relationships between water quality parameters and land cover types. The results are shown below in Table 84. Red equals a statistically significant negative correlation and green a statistically significant positive correlation.

		HID	MID	LID	OSD	Cult.	Past.	Grass.	Decid. For.	Evergr. For.	Mix For.	Scrub / Shrub	For. Wet.	Scrub / Shrub Wet.	Emerg. Wet.	Bare Land	Open Water
Temp	Corr.	.121	.098	.079	.181	.044	-.274	-.114	-.079	-.113	-.222	-.198	.047	.021	.103	.015	-.116
	Sig.	.489	.576	.652	.297	.801	.112	.514	.654	.517	.200	.255	.791	.903	.556	.931	.508
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
DO	Corr.	-.006	.022	-.204	.064	.106	.201	.331	.052	.215	.446**	.316	-.004	-.214	-.514**	.229	-.191
	Sig.	.973	.901	.240	.713	.545	.247	.052	.767	.215	.007	.064	.980	.218	.002	.186	.271
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
DO % Sat	Corr.	.017	.035	-.173	.076	.086	.176	.351*	.062	.218	.430**	.314	.001	-.208	-.504**	.276	-.188
	Sig.	.921	.842	.322	.662	.622	.311	.039	.722	.209	.010	.067	.994	.231	.002	.109	.278
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35

		HID	MID	LID	OSD	Cult.	Past.	Grass.	Decid. For.	Evergr. For.	Mix For.	Scrub / Shrub	For. Wet.	Scrub / Shrub Wet.	Emerg. Wet.	Bare Land	Open Water
NH3	Corr.	.020	-.016	.125	-.220	.016	-.074	-.318	-.041	-.276	-.321	-.332	-.015	.219	.501**	-.377*	.066
	Sig.	.908	.927	.475	.204	.929	.674	.063	.815	.109	.060	.051	.933	.205	.002	.025	.707
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
NO3	Corr.	-.129	-.262	-.409*	-.397*	.633**	.359*	.033	-.121	-.357*	-.060	-.160	-.041	.105	.079	.111	-.430**
	Sig.	.461	.128	.015	.018	.000	.034	.852	.489	.035	.731	.359	.816	.548	.651	.526	.010
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TKN	Corr.	-.276	-.165	-.079	-.269	.205	.092	-.210	.009	-.329	-.413*	-.221	-.026	.235	.542**	-.114	-.121
	Sig.	.109	.344	.651	.119	.238	.601	.225	.961	.053	.014	.202	.883	.174	.001	.516	.487
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TP	Corr.	-.243	-.218	-.143	-.238	.273	.155	-.192	-.014	-.381*	-.401*	-.252	-.080	.312	.623**	.030	-.116
	Sig.	.159	.209	.414	.168	.113	.373	.269	.934	.024	.017	.145	.648	.068	.000	.865	.508
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TSS	Corr.	-.069	.047	-.108	-.199	.090	.027	-.054	-.148	-.337*	-.336*	-.123	-.165	-.111	.144	.179	-.202
	Sig.	.694	.788	.539	.251	.606	.878	.758	.396	.048	.048	.480	.342	.524	.410	.304	.245
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Turbidity	Corr.	.056	.206	.098	-.052	-.085	-.165	-.110	-.166	-.246	-.304	-.112	-.121	-.206	.035	.326	-.181
	Sig.	.749	.235	.575	.768	.629	.344	.529	.341	.154	.076	.522	.488	.235	.844	.056	.298
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TS	Corr.	.381*	.412*	.241	-.051	-.107	-.266	-.243	-.295	-.413*	-.060	-.292	-.394*	-.268	.059	-.235	-.211
	Sig.	.024	.014	.163	.771	.540	.122	.160	.086	.014	.734	.088	.019	.120	.738	.174	.224
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TDS	Corr.	.395*	.450**	.212	-.005	-.130	-.218	-.155	-.248	-.312	.086	-.172	-.435**	-.324	-.064	-.200	-.212
	Sig.	.019	.007	.221	.978	.456	.209	.375	.150	.068	.623	.322	.009	.058	.714	.249	.221
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
E coli	Corr.	.099	.249	-.006	-.258	.043	-.056	-.060	-.459**	-.306	.145	-.304	-.356*	-.465**	-.540**	-.066	-.402*
	Sig.	.572	.149	.975	.135	.804	.749	.734	.006	.074	.407	.076	.036	.005	.001	.705	.017
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
pH	Corr.	.048	.009	-.183	-.004	.018	.148	.444**	.047	.239	.377*	.362*	.023	-.252	-.524**	.290	-.057
	Sig.	.783	.959	.293	.982	.917	.397	.008	.788	.166	.026	.033	.896	.144	.001	.092	.745
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Cond	Corr.	.430**	.445**	.271	-.075	-.091	-.283	-.265	-.355*	-.400*	.018	-.373*	-.440**	-.355*	-.037	-.166	-.258
	Sig.	.010	.007	.116	.671	.603	.100	.124	.036	.017	.918	.027	.008	.036	.832	.341	.135
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Chl	Corr.	.542**	.494**	.350*	.146	-.101	-.364*	-.278	-.391*	-.351*	.084	-.466**	-.272	-.370*	-.077	-.038	-.180
	Sig.	.001	.003	.039	.403	.564	.031	.106	.020	.039	.630	.005	.114	.029	.659	.827	.300
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
TOC	Corr.	-.213	-.185	-.046	-.143	.138	.058	-.164	.064	-.284	-.352*	-.179	-.011	.322	.674**	-.078	.032
	Sig.	.218	.288	.792	.412	.429	.742	.346	.715	.099	.038	.303	.952	.059	.000	.656	.854
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
COD	Corr.	-.278	-.176	-.085	-.146	.218	.051	-.287	-.004	-.353*	-.405*	-.240	-.041	.253	.547**	-.013	-.122
	Sig.	.106	.310	.629	.401	.209	.770	.094	.982	.038	.016	.164	.817	.142	.001	.940	.484
	N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35

Table 84 Water quality land cover correlation analysis results

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

From this analysis we can see some of the negative impacts associated with human land uses and the water quality benefits provided by natural land cover. For example strong positive correlations were observed between the percentage of agriculture land cover and nitrates and the percentage of development showed strong positive correlations with total solids (TS), total dissolved solids (TDS), conductivity, and chlorides (chl). The water quality benefit associated with forest cover was observed with a strong positive relationship with dissolved oxygen, and negative correlations with *E. coli*, conductivity, nitrate, total phosphorus, turbidity, chlorides, total organic carbon and chemical oxygen demand. Similarly there was a strong negative correlation observed between wetlands and *E. coli*.

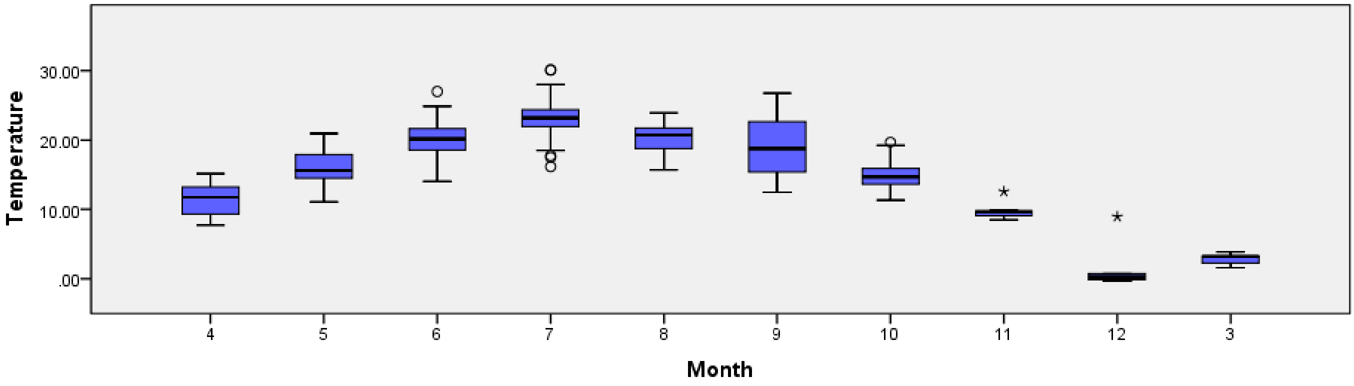
The correlation analysis indicates that wetlands in our watershed can act as sinks or sources. For example there is a strong positive correlation between the percentage of emergent wetlands and total phosphorus (source) and a strong negative correlation with E. coli concentrations (sink). A number of factors influence how the wetland will "behave" in this capacity such as wetland type, hydrologic conditions, season, and length of time the wetland has been subjected to loading. Human impacts can lead to considerable changes in chemical cycling in wetlands and their ability to assimilate these often increased inputs is not limitless.

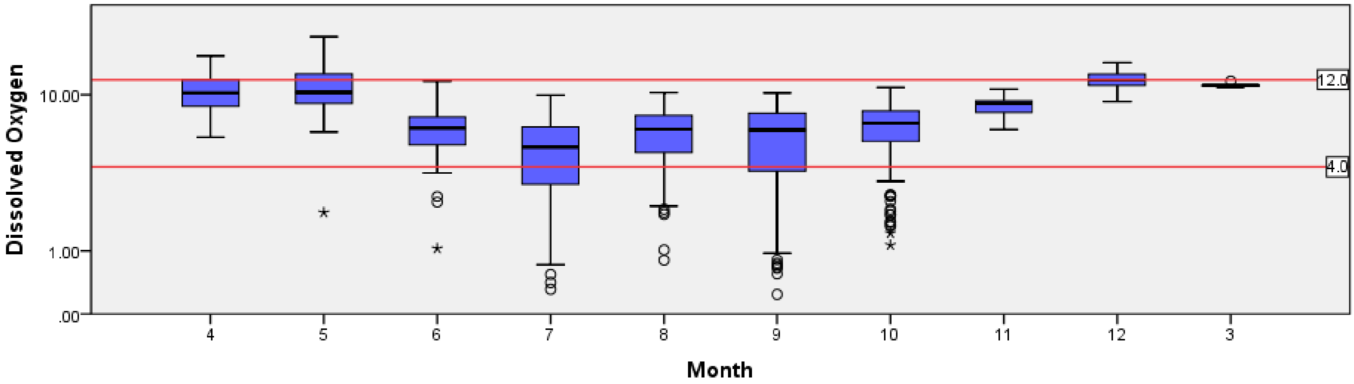
Hydrologic Condition Variability

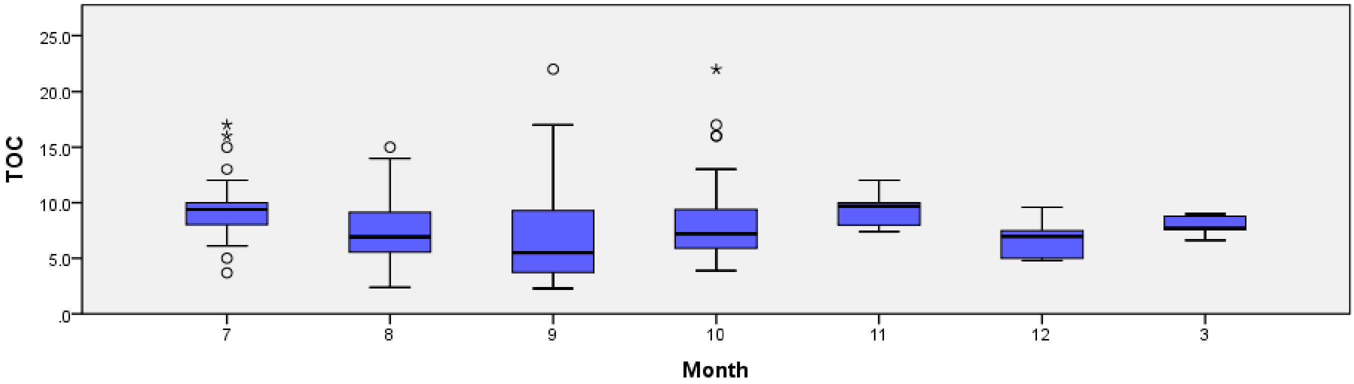
Site load duration curves for nutrients and sediment (TSS) show that water quality target values are most often exceeded during midrange to high flow conditions indicating the primary sources are runoff and streambank erosion related. Occasionally, target values are exceeded during dry stream flow conditions indicating pollutant loading from upland impervious areas and within the riparian zone. Load duration curves for each site are included in Appendix B of the Deep River-Portage Burns Waterway TMDL study http://www.in.gov/idem/nps/3893.htm.

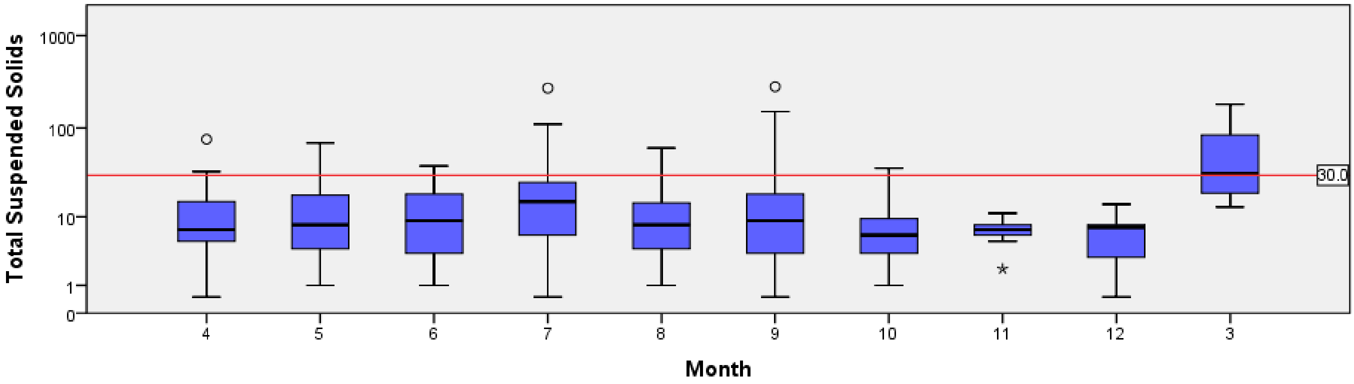
Temporal Variability

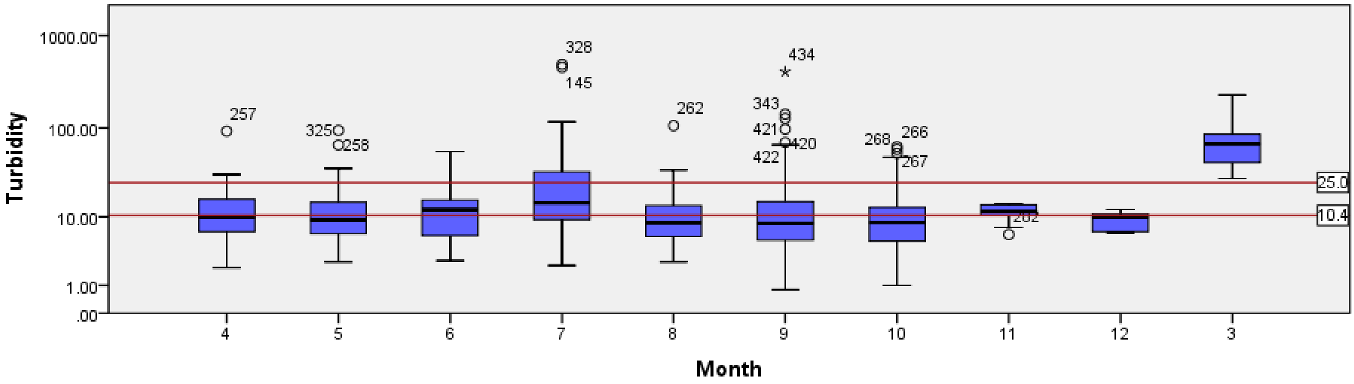
Statistically significant monthly/seasonal variations were observed in dissolved oxygen, total organic carbon, sediment, and nutrient concentrations (Figure 212). Dissolved oxygen concentrations most frequently fell below the 4 mg/L water quality standard during the summer months with warmer water temperatures and lower stream flows. Total suspended solids (TSS) and turbidity levels most frequently exceeded target values during March. This observation generally corresponds to the melting and subsequent runoff of the nearly 60 inches of snow that fell on the region between November 2013 and March 2014 (Table 5). Total phosphorus showed a small peak in July, with larger peaks being observed in September and December. Nitrate concentrations were at the highest during the fallow months of November and December. Ammonia concentration were generally highest in June and September. No water quality monitoring occurred in January or February because of ice cover at the stream sites.




Dissolved Oxygen
10.00
1.00
.00
12.0
4.0
4
5
6
7
8
9
10
11
12
3
Month


TOC
25.0
20.0
15.0
10.0
5.0
.0
7
8
9
10
11
12
3
Month


Total Suspended Solids
1000
100
10
1
0
30.0
4
5
6
7
8
9
10
11
12
3
Month


Turbidity
1000.00
100.00
10.00
1.00
.00
25.0
10.4
257
325
258
328
145
262
434
343
421
420
422
268
266
267
262
4
5
6
7
8
9
10
11
12
3
Month

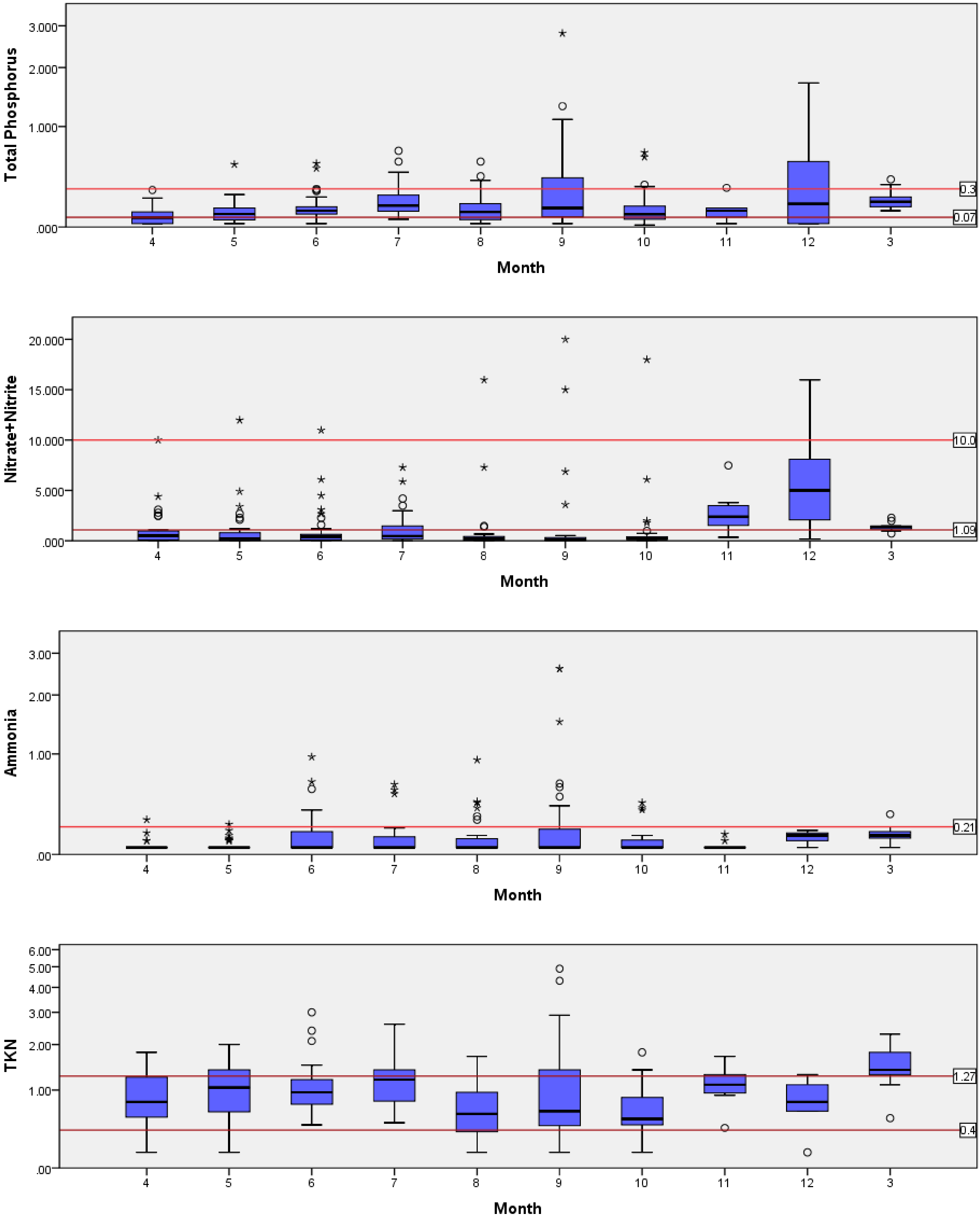


Figure 212 Box plots illustrating monthly dissolved oxygen, sediment and nutrient concentrations within the watershed

Stressor Linkage Analysis

A statistical analysis following methodologies outlined by Morris et al (2005) was used to further evaluate and identify the key stressors and linkages that could better explain the observed biotic impairments. The first step was to conduct a cluster analysis, grouping sites with similar fish and macroinvertebrate community structures (i.e. species and percent composition). Assuming that these community structures are the result of external driving forces and that those forces are identifiable, these groupings were used to evaluate physical and chemical variables (stressors) relative to the identified groupings. The resulting clusters (Figure 213 and Figure 214) were used as grouping variables in a Kruskal-Wallis analysis of variance (ANOVA) by ranks test to evaluate the water chemistry, habitat and land cover variables.

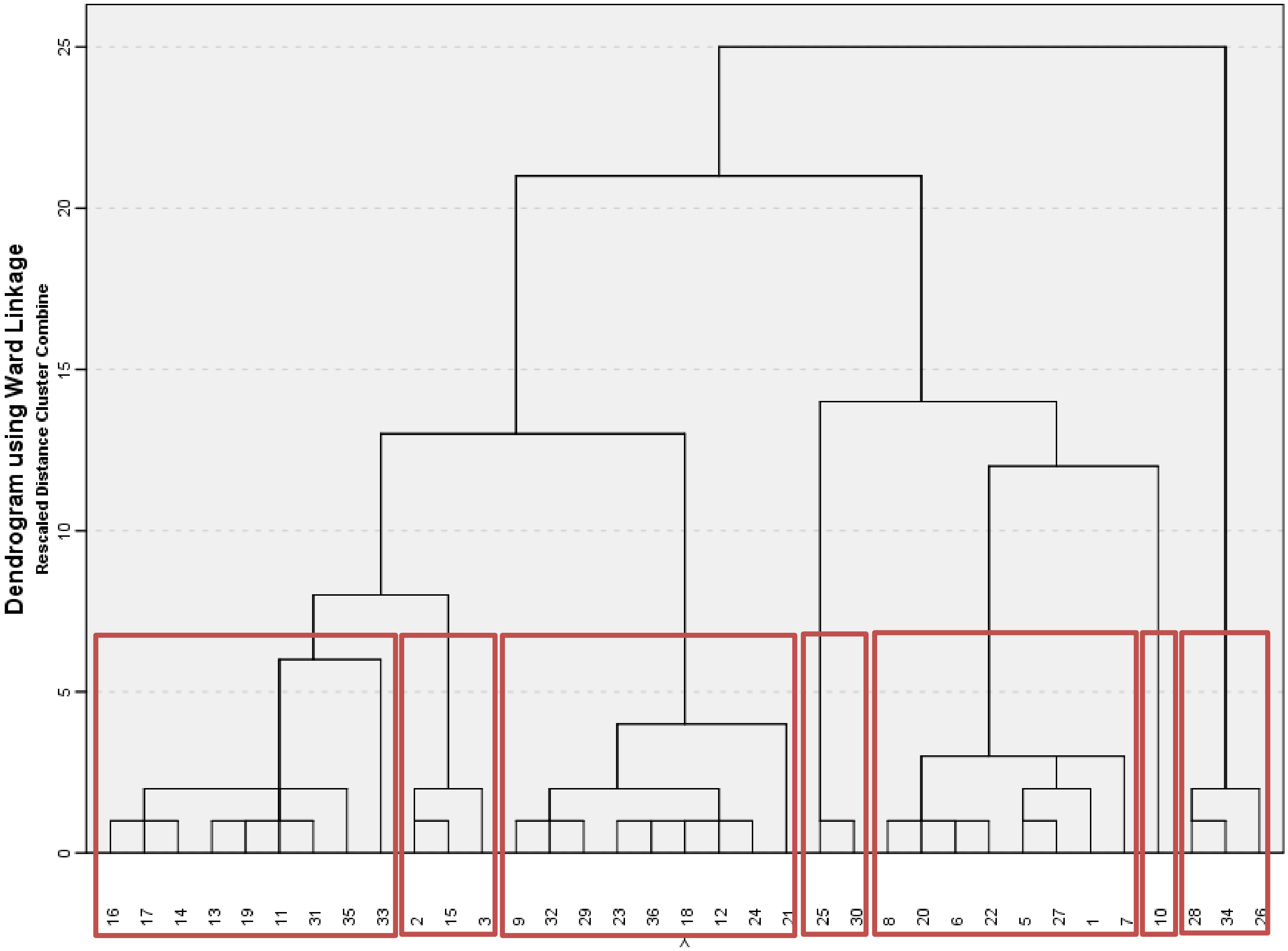


Figure 213 Fish Community Cluster Analysis

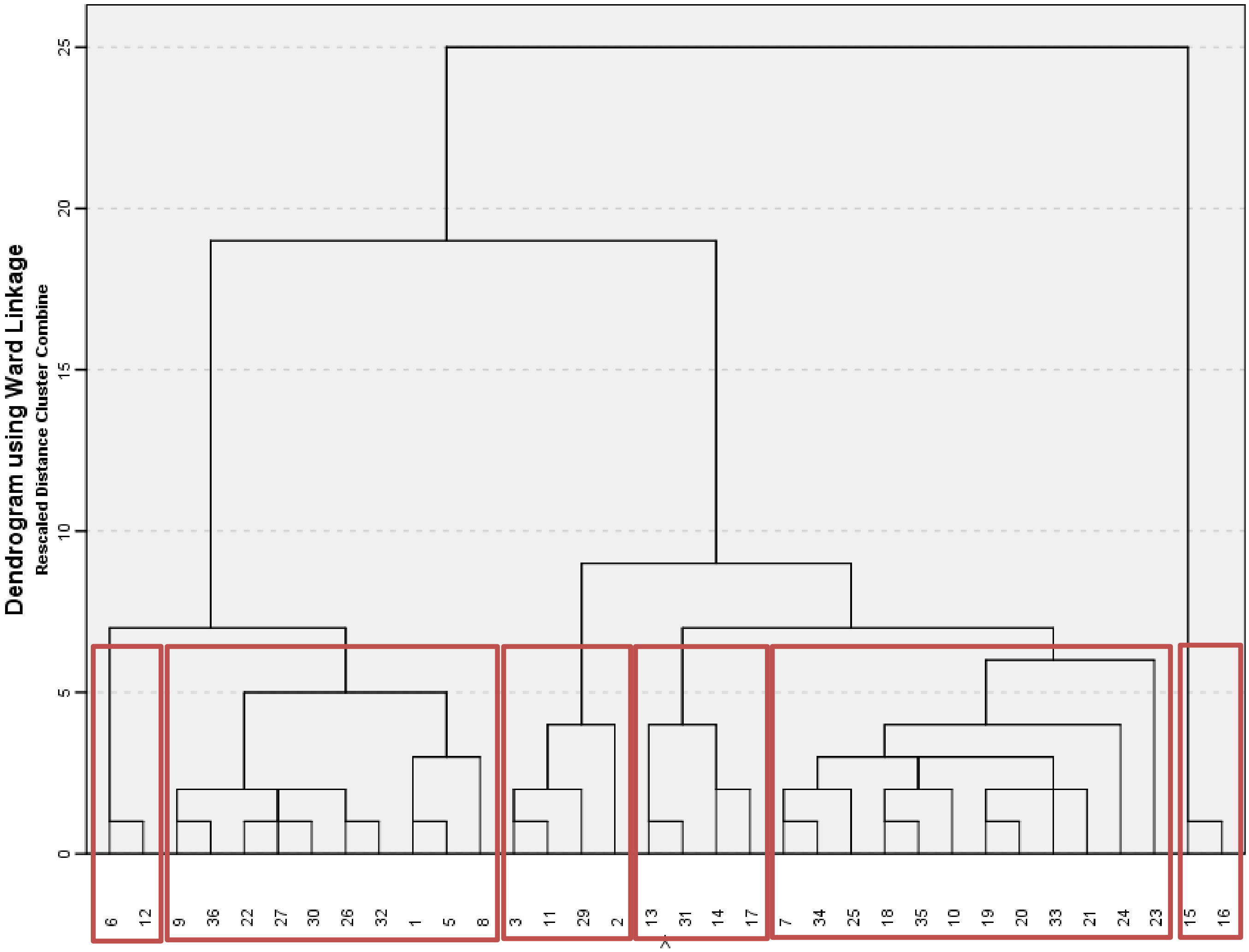


Figure 214 Macroinvertebrate community cluster analysis

The results of the Kruskal-Wallis ANOVA test (Table 85) showed that six water chemistry, one land cover, and three habitat variables (stressors) were significantly predictive of fish community structure. Four water chemistry, five land cover, and three habitat variables were significantly predictive of benthic macroinvertebrate community structure. The habitat variables effectively capture the influence of channelized streams/regulated drains on biotic communities within the watershed.

Variable	**Fish Significance** (α=0.05, CL=95%)	**Macroinvertebrate Significance** (α=0.05, CL=95%)
Water Chemistry		
Temperature	.014	
Dissolved Oxygen (DO)	.036	.019
Dissolved Oxygen % Saturation		.024
Ammonia		.019
Turbidity	.036	
E. coli	.026	
pH		.017
Total Organic Carbon (TOC)	.028	

Variable	**Fish Significance** (α=0.05, CL=95%)	**Macroinvertebrate Significance** (α=0.05, CL=95%)
Chemical Oxygen Demand (COD)	.046	
Land Cover		
Wetland	.022	.026
Forest		.040
Scrub/Shrub		.021
Riparian Deciduous Forest		.003
Riparian Scrub/Shrub		.015
Physical Habitat		
Channel Morphology	.019	.018
Riparian		.027
Gradient	.001	.010
Embeddedness	.022	

Table 85 Variables significantly predictive of the fish and macroinvertebrate community structure

The variables found to be significantly predictive of community structures were further evaluated using a Principle Components Analysis (PCA). This type of analysis is often used to identify which factors explain most of the variance observed within a larger set of variables and to generate hypotheses regarding causal mechanisms. Variables were normalized and standardized (z-scores) and evaluated for strong correlations ($r > 0.8$) using Spearman's correlation before conducting this analysis. Chemical oxygen demand was dropped from further consideration due to its strong correlation to total organic carbon for fish while pH and dissolved oxygen percent saturation were dropped due to their strong correlation to dissolved oxygen.

The result of the principal components analysis explaining fish community structure is shown in Figure 215. Three statistically significant dimensions were identified which collectively describe 68% of the variability. Loading values greater than 0.75 signify a "strong" correlation, while values between 0.75 and 0.50 indicate "moderate" correlation and values between 0.50 and 0.30 denote "weak" correlation.

Component 1 explains 34% of the variation and shows a strong positive correlation with dissolved oxygen (DO) and a strong negative correlation with total organic carbon (TOC). Moderate, positive correlations were observed with three habitat related metrics including channel morphology, stream gradient and substrate embeddedness (inverse metric). A moderate, negative correlation was observed with emergent wetland (LC15) habitat. Component 2 explains an additional 18% of the variation and shows a strong negative correlation with wetland habitat. Moderate, positive correlations where observed with *E. coli* and turbidity and a moderate, negative correlation was observed with emergent wetland (LC15) habitat. Component 3 explains an additional 15% of the variation with a strong positive correlation with water temperature and moderate negative correlation with *E. coli*.

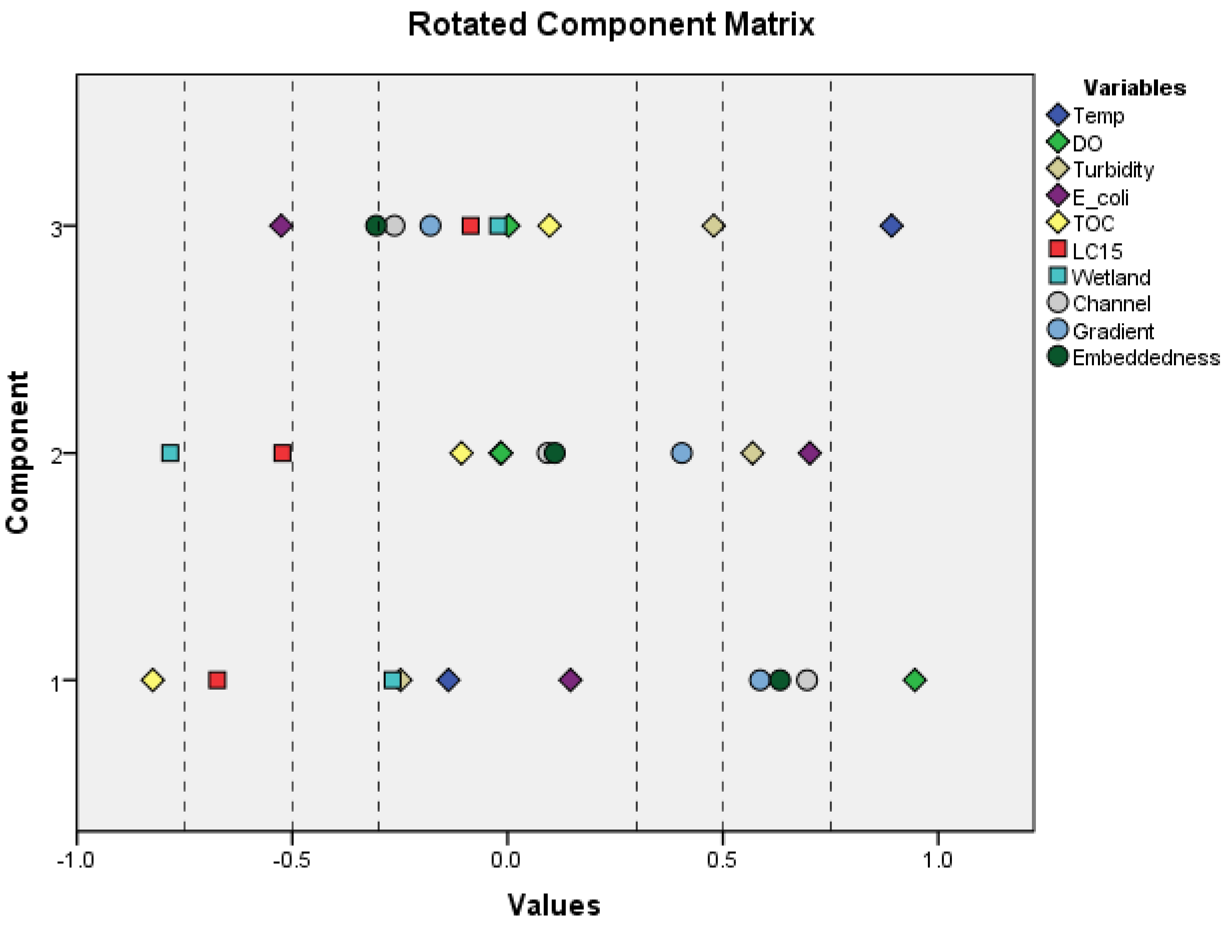


Figure 215 Fish community principle component analysis results

Results of the principal components analysis used to evaluate which factors are most influential in macroinvertebrate community structure are shown in Figure 216. Two statistically significant dimensions were identified which collectively describe 67% of the variability.

Component 1 explains 40% of the variation and shows a strong positive correlation with dissolved oxygen (DO), channel morphology, and riparian deciduous forest (Rip9). Moderate, positive correlations were observed with stream gradient and riparian scrub/shrub habitat (Rip12). A moderate, negative correlation was observed with ammonia. Component 2 explains an additional 27% of the variation and shows a strong positive correlation with forest and wetland habitat. Moderate, positive correlations where observed with forest and riparian deciduous forest (Rip9) habitat.

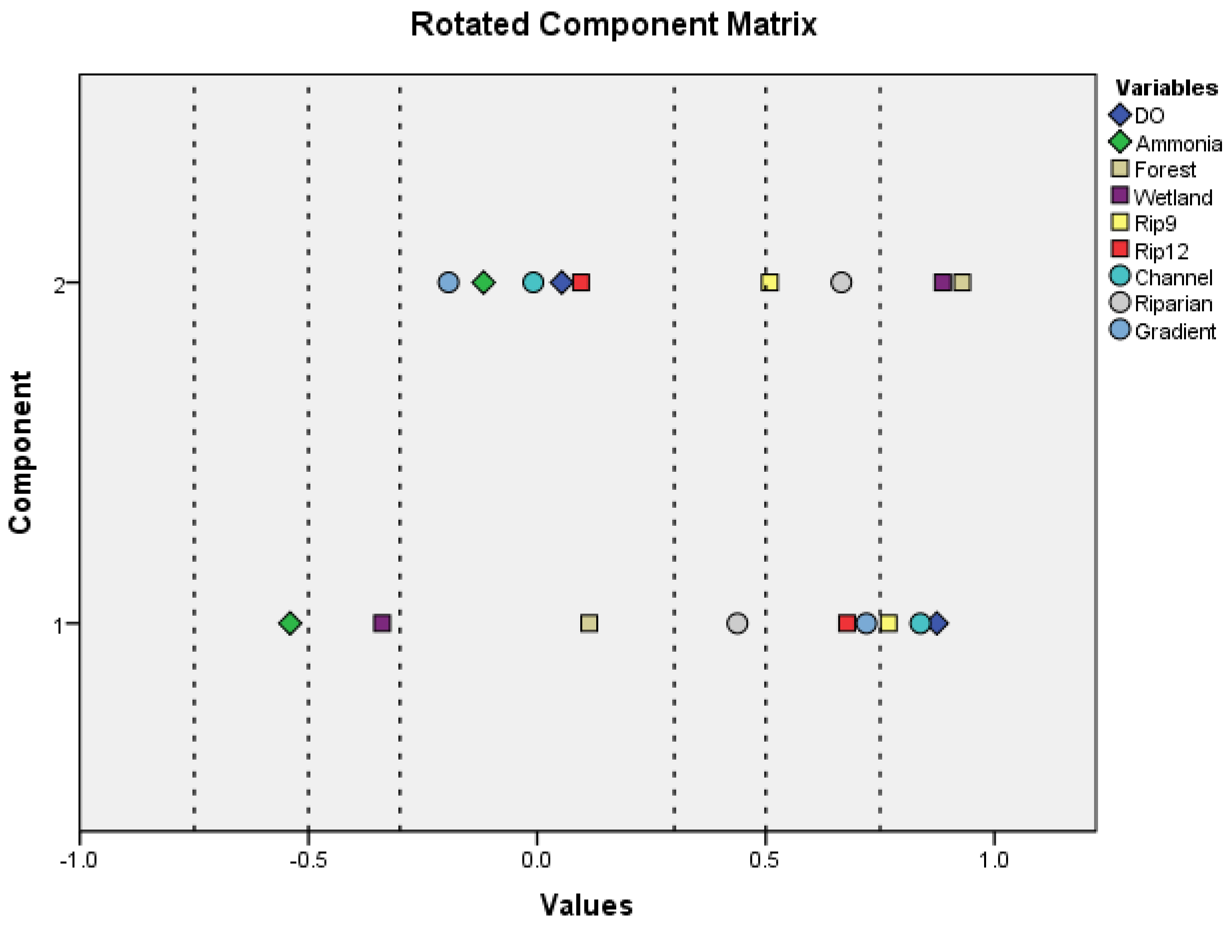


Figure 216 Macroinvertebrate community principal component analysis results

The linkage analysis shows that dissolved oxygen, channel morphology, and riparian forest are the most significant factors in explaining fish and macroinvertebrate community structure in the watershed. Restoration actions should focus heavily on these parameters. Sites that maintained good dissolved oxygen levels throughout the year (4-12 mg/L), had good channel morphology (i.e. good sinuosity, pool/riffle/run development, not channelized or had recovered, and were stable), and forested riparian zone typically had healthier fish and macroinvertebrate communities.

Healthy, functioning fish and macroinvertebrate communities occurs when the following conditions are present (Harman et al, 2012):

1. Continuous upstream streamflow sources, as removal of impoundments and excessive water consumption for human activities will provide adequate streamflow throughout the year;
2. Floodplain connectivity and bankfull channel, which dissipate energy of large storm events to prevent excessive scouring of substrates used for reproduction, and prevent sediment inundation of substrate habitat;
3. Healthy hyporheic zones (the region where shallow groundwater and surface water mix along the streambed) , which provide habitat and food resources;

4. Bed form diversity and in-stream structures, which create diverse habitats for feeding and reproduction, dissipate stormflow energy; provides opportunities for organic carbon storage and retention, provide substrates such as large woody debris, and provide scour pools for reproduction, feeding and shelter;
5. Channel stability, which prevents sediment inundation of habitat and excessive turbidity that is contributed from channel erosion;
6. Riparian community, which provides inputs for food resources, provides shade for cooler temperatures and provides vegetative roots for available habitat; and
7. Adequate dissolved oxygen, which is required for survival and health.

Based on the data that has been collected and presented, issues with conditions 1-2 and 4-7 are readily apparent, to varying degrees in watershed.

Also, when all factors are considered together an interrelated or hierarchical cause-and-effect relationship is apparent. The "stream functions pyramid" shown in Figure 217 is provided as a visual representation to help explain these relationships. The pyramid is based on a framework adopted by the US Army Corps of Engineers (USACE) for evaluating stream restoration projects. The pyramid simplifies a suite of 15 functions that the USACE determined to be critical to the health of a stream and riparian ecosystem (Harman et al, 2012).

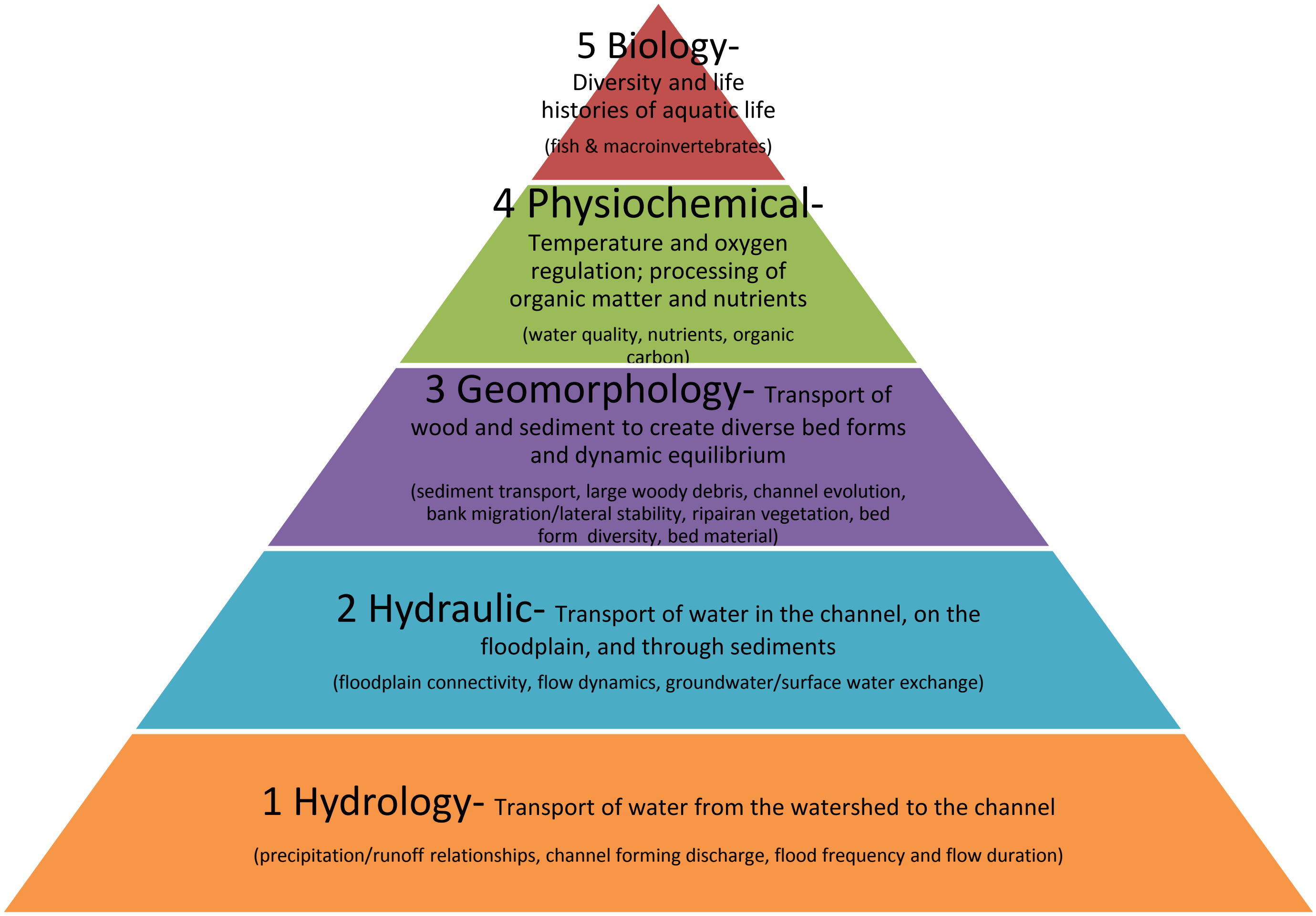


Figure 217 Stream functions pyramid

This functional based framework infers that restoration activities that occur at lower levels will provide a functional lift at higher levels. The pyramid also infers that the likelihood of restoring aquatic communities or water quality without also addressing lower level functions is problematic at best.

The principal components analysis results indicate that geomorphology related measures such as channel morphology, bed material, and riparian vegetation explain a significant portion of variability observed in aquatic communities. Hydraulic function parameters such as floodplain connectivity were not evaluated directly in the field during the baseline assessment. However, given the extent of stream channelization and impervious cover in the watershed it is reasonable to assume that floodplain connectivity is an issue along at least some stream reaches in the watershed such as Willow Creek and Main Beaver Dam Ditch. At the hydrology level, the shape of the flow-duration curve presented in Figure 19 indicates variable stream flows as a result of increased surface runoff and reduced watershed storage.

5.2 Analysis of Stakeholder Concerns

Stakeholder concerns generated through the public/ steering committee meetings are listed in Table 86. The steering committee helped evaluate whether the available data and evidence supported each concern. The steering committee also determined whether or not it was a concern they wished to focus. The only concern that the steering committee chose not to focus on at this time was the loss of cropland to development. This can be a complex issue with both positives (ex. less natural area converted) and negatives (ex. loss of productive farmland).

Concerns	Supported by Data?	Evidence	Able to Quantify?	Within Project Scope?	Steering Committee Wants to Focus On?
Stream Habitat Loss and Riparian Encroachment	Yes	24 of the 35 stream sites (69%) assessed by IDEM had QHEI scores <51 indicating that habitat quality in these reaches was generally not conducive to supporting a healthy warm water fish community. The average "riparian quality" metric score from the QHEI was 5.5 with a range of 3 to 9 (12 possible points). An analysis of land cover types within a 30-meter buffer adjacent to streams showed that human land uses account for 35 to 65% of the area with an average of 52%.	Yes	Yes	Yes
Wetland Habitat Loss and Degradation	Yes	Based on hydric soils data, nearly 28,000 acres (75%) of wetland habitat has been converted to developed or agricultural land uses.	Yes	Yes	Yes
Species Loss	Yes	Species metric scoring (# species) for the Index of Biotic Integrity indicates that 26 sites fall below expectations for the ecoregion.	Yes	Yes	Yes
Need for Conserved	Yes	The Chicago Wilderness Green Infrastructure Vision 2.1 identified	Yes	Yes	Yes

Concerns	Supported by Data?	Evidence	Able to Quantify?	Within Project Scope?	Steering Committee Wants to Focus On?
Open Spaces, Riparian Corridor Acquisition, Recreational Access		37,622 acres (58 mi²) of land as a priority for preservation. Approximately 17,000 acres (27 mi²) of land is currently protected according to DNR managed lands data. Overall, human land uses account for approximately 57% of the riparian land cover in the watershed.			
Habitat Restoration and Long-Term Management of Natural Areas	Yes	Aquatic and terrestrial invasive species have been documented in the watershed by various agencies and non-government organizations. High quality natural areas and ETR species are documented in the watershed by Indiana Natural Heritage Data Center Local land trusts and managers such as Shirley Heinze, The Nature Conservancy, Save the Dunes, DNR and Lake County Parks Department have invested significant resources in managing natural areas.	Yes	Yes	Yes
Terrestrial and Aquatic Invasive Species	Yes	Round goby and alewife collected by IDEM assessment crews at three sites below Deep River dam in Lake Station. At least 13 terrestrial, invasive plant species have been identified in the watershed. Several others have been identified as probable.	Yes	No	Yes
Negative Impact of Impaired Waterways to Recreational Use, Property Values, and Economic Development	Yes	All 35 monitoring sites have median *E. coli* concentrations that exceed the 235 CFU/100 mL single sample water quality standard. 24 of the 35 (69%) monitoring sites have impaired fish communities. Seven (20%) sites had seven or fewer fish collected. Signs posted inside the Portage Lakefront and Riverwalk warn the public not to swim inside the harbor due to high bacteria levels.	Yes	Yes	Yes
Coordination Between Municipalities, Business, and Residents	No	As a general observation, the level of coordination is highly variable and dependent on many factors.	Uncertain	Yes	Yes

Concerns	Supported by Data?	Evidence	Able to Quantify?	Within Project Scope?	Steering Committee Wants to Focus On?
Enforcement of Existing Regulations Protective of Stream Health	Yes	Over 160 unauthorized wetland impact violations have been investigated by the U.S. Army Corps of Engineers between 2000 and March 2015 in the watershed.	Yes	Yes	Yes
Reconciling Need for Drainage While Also Protecting Water Quality and Aquatic Life	Yes	Of the approximate 112 miles of regulated drain within the watershed, 110 miles are listed with an impairment. Significantly negative correlations exist between regulated drains and: • dissolved oxygen • pH • QHEI, channel quality, riffle/run, and gradient metrics • Silt and embeddedness QHEI sub-metrics • Simple lithophils IBI metric • Intolerant species and sprawler mIBI metrics Significantly positive correlations exist between regulated drains and: • Ammonia • Total Kjeldahl nitrogen • Total phosphorus • Total organic carbon • Chemical oxygen demand • Insectivore IBI metric	Yes	Yes	Yes
Maintenance of Existing Plans	Yes	No organizational structure was put in place to implement the Deep River-Turkey Creek and West Branch Little Calumet River WMP's once they were completed. Projects were largely independent of group effort.	Yes	Yes	Yes
Loss of Cropland to Development	Yes	Between 1985 and 2010, 6,644 acres of agricultural land (-17%) was converted to other uses while development expanded by nearly 10,578 acres (26%).	Yes	Yes	No
Some Absentee Agricultural Landowners Seem to be Land Speculators with Less	No	Agricultural parcels posted/listed for sale near prime development areas. However due to privacy requirements associated with the Farm Bill program, operator or site information is restricted to the general public so	No	Uncertain	Yes

Concerns	Supported by Data?	Evidence	Able to Quantify?	Within Project Scope?	Steering Committee Wants to Focus On?
Interest in Investing in BMPs to Protect Water Quality		there is a degree of uncertainty associated with BMP implementation.			
Ability of Watershed to Store and Filter Storm Water Runoff While Providing Habitat	Yes	In a Wisconsin DNR publication that focused on small wetlands and wetland loss, Trochlell and Bernthal (1998) compiled research that showed there was a threshold in which watersheds with less than 10% wetland area often experienced pronounced negative hydrological and water quality impacts, including deceased stream stability, higher peak flows, lower base flows and increased suspended solid loading rates. Only 8% of the land area in our watershed is wetland habitat. Historically it would have been closer to 32%. The approximate value of ecosystem services provided by the Green Infrastructure Vision within our watershed is: • $31 million in water purification • $493 million in water flow regulation/ flood control • $126 million in groundwater recharge	Yes	Yes	Yes
Excessive Sediment and Nutrient Loading from Urban and Agricultural Land Uses	Yes	Biotic impairments co-occur where the data indicates sediment and nutrients are at an intensity and duration that could result in a change in the ecological condition. Median concentrations of sediment and nutrient target values protective of fish and macroinvertebrate communities exceeded. • TSS- 1 site (2.9% of sites) • Turbidity- 16 sites (45.7% of sites) • TP- 24 sites (68.6% of sites) • Nitrate- 6 sites (17.1% of sites) • TKN- 23 sites (65.7% of sites)	Yes	Yes	Yes

Concerns	Supported by Data?	Evidence	Able to Quantify?	Within Project Scope?	Steering Committee Wants to Focus On?
		• Ammonia- 10 sites (28.6% of sites)			
		There is a significant correlation between nutrient concentrations and agricultural land uses.			
		There is a significant correlation between chloride concentrations and developed land uses.			
Increased Storm Water Runoff Volume Causing Streambank and Shoreline Erosion	Yes	USGS stream gage at Lake George outlet indicates increasing trends for annual peak discharge and precipitation. However, annual peak discharge is increasing at a much higher rate (57%) than annual total precipitation (11%) over period of record (1947-2009).	Yes	Yes	Yes
		The flow-duration curve suggests a system influenced by increased runoff and loss of storage.			
		Impervious surface cover analysis shows that seven of the nine subwatersheds are impacted by impervious cover, exceeding the 10% threshold classification for a sensitive stream.			
		31 of the 34 (91%) monitoring sites had moderate levels of streambank erosion documented on the QHEI			
Sedimentation of Lake George and Burns Ditch	Yes	In 1993 the U.S. Army Corps of Engineers (USACE), Chicago District, initiated an extensive evaluation of Lake George and its major tributaries and later published a 1995 Planning/ Engineering feasibility report for the dredging of Lake George.	Yes	Yes	Yes
		In 2000, the City of Hobart proceeded with a limited dredging of Lake George that removed 590,000 cubic yards of sediment at a cost of over two million dollars.			
		In 2003, the USACE released the Burns Ditch/ Waterway Sediment Transport Modeling Phase I Report with the following findings: • Sediment reduced the average depth of water in Lake George			

Concerns	Supported by Data?	Evidence	Able to Quantify?	Within Project Scope?	Steering Committee Wants to Focus On?
		from approximately 6-8 ft. to 1-3 ft. • Sediment in the lake is mostly from intensive agriculture and development construction in the upstream watershed. • Sediment on the lake bottom is formed by fine silt and clay (90-98%). • Channel erosion on the river reach downstream of Lake George appears to be an important source of sediment that ultimately settles at mouth of Burns Ditch.			
		Bathymetric mapping of Lake George for the Deep River Flood Risk Management Plan shows that 70,000 cubic yards of sediment have accumulated over the past 14 years (2001-2014). This translates to approximately 5,000 cubic yards/year.			
		Median TSS concentrations drop from 14 mg/L at Site 12 on Deep River upstream of Lake George to 4 mg/L at Site 8 immediately downstream of the Lake George dam (71% reduction) indicating sediment deposition in the lake.			
Failing Septic Systems	Yes	City of Hobart and Indiana State Department of Health confirm several houses have failed septic systems with absorption fields located within Deep River floodplain.	Yes	Yes	Yes
		Strong positive correlation observed between *E. coli* and total dissolved solids, conductivity and chloride median concentrations indicating presence of human sources.			
Flooding, Floodplain Encroachment, and Stream Flashiness	Yes	Analysis of land cover types within the 100-yr. floodplain show that agriculture accounts for 22% of the floodplain land area, development 21%, and developed open space 9%.	Yes	Yes	Yes
		Impervious surface cover analysis shows that seven of the nine			

Concerns	Supported by Data?	Evidence	Able to Quantify?	Within Project Scope?	Steering Committee Wants to Focus On?
		subwatersheds are impacted by impervious cover. USGS stream gage data shows a steady increase in annual peak flows. Flow duration curve points towards a system influenced by runoff and loss of storage.			
Negative Impacts Associated with Dams	Yes	Streambank erosion downstream of Lake George and Deep River dams documented in IDEM habitat assessments. Findings from the USACE Burns Ditch/ Waterway Sediment Transport Modeling Phase I Report state that channel erosion on the river reach downstream of Lake George appears to be an important source of sediment due to rapid fluctuation in discharge. Impaired biotic impairments in upstream and downstream reaches of the Lake George and Deep River dams. Deep River dam is an obstacle for recreational use of the river as a water trail.	Yes	Yes	Yes
Public Involvement	No	Attendance at public/stakeholder meeting. Participation in Hoosier Riverwatch training workshops.	Yes	Yes	Yes, as overall stakeholder awareness and collaboration
Soil Health	Yes	In 2103, approximately 45% of the acreage in corn production in Lake and Porter Counties still used conventional tillage. In 2013, no-till was only used on 20% of the acreage in corn production in Lake County and 5% in Porter County.	Yes	Yes	Yes
Combined Sewer and Sanitary Sewer Overflows	Yes	Crown Point WWTP CSO Events • 2009- 10 events • 2010- 10 events • 2011- 20 events • 2012- 5 events • 2013- 15 events Gary Sanitary District WWTP CSO Events	Yes	Yes	Yes

Concerns	Supported by Data?	Evidence	Able to Quantify?	Within Project Scope?	Steering Committee Wants to Focus On?
		• 2009- 64 events • 2010- 80 events • 2011- 44 events • 2012- 24 events • 2013- 48 events			
Litter Left Behind After Floodwaters Recede	Yes	Litter deposited in floodplains after floodwaters receded. Litter accumulated in woody debris within stream channel.	Yes	Yes	Yes
		Litter collected by volunteers during stream clean up (NWI Paddlers Association event on Deep River below Lake George).			
		Litter accumulated on beach inside Burns Waterway harbor.			

Table 86 Analysis of stakeholder concerns