A Water Quality Summary of the Bear River

Tip of the Mitt Watershed Council, 2010

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INTRODUCTION

Water quality data have been compiled to assess the overall water quality of the Bear River Watershed, as well as that of individual monitoring sites. Water quality data have been collected from the Bear River and its tributaries over the last several decades and are available from the Michigan Department of Environmental Quality (MDEQ), Tip of the Mitt Watershed Council (TOMWC), and Little Traverse Bay Bands of Odawa Indians (LTBB). Water quality data from the MDEQ includes “Legacy” data, which is historical data (prior to year 2000) from the United States Environmental Protection Agency STORET database. Physical, chemical, and biological water quality data are available for multiple sites on the river, as well as Spring Brook and Hay Marsh Creek. Water quality data from Walloon Lake, which forms the western headwaters of the Bear River, are not included in this report.

Over 50 physical and chemical parameters have been monitored at sites in the Bear River Watershed (see Appendix 1 for full list of parameters). Physical water quality data have been collected at most sites and include commonly monitored parameters such as water temperature, pH, conductivity, and dissolved oxygen. A large variety of chemical data have been collected from the Bear River and its tributaries, including many different forms of nutrients, a variety of metals, alkalinity, hardness, chloride, and more. In addition, discharge data (volume of water per unit of time) exists for several sites.

Biological and bacteriological monitoring data have also been collected at multiple sites in the Watershed. Aquatic macroinvertebrate community health has been assessed at various locations by the MDEQ, TOMWC, and LTBB. Bacteriological monitoring data is limited; collected available from the MDEQ and dating from the 1970s.

The goal of compiling and analyzing water quality data is to provide a tool to assist in efforts to manage and protect the Bear River. There are many applications for the information presented in this report. Water resource organizations, local governments, and others can use the information to prioritize restoration and protection efforts, evaluate restoration projects, determine trends over time, and more.

BEAR RIVER WATERSHED

Description:

The Bear River is located in the Northwest Lower Peninsula of Michigan. Its main channel flows 14.5 miles from Walloon Lake north to Lake Michigan, emptying into Little Traverse Bay at Petoskey (Figure 1). The average slope of the main channel is approximately seven feet per mile. Major tributaries of the Bear River include Hay Marsh Creek, a warm-water tributary draining extensive wetlands in the southern headwaters, and Spring Brook, a cold-water tributary draining the headwaters to the southeast. Walloon Lake is one of just a few lakes in the watershed and by far the largest with 4,600 acres of surface area and a maximum depth of 100 feet.

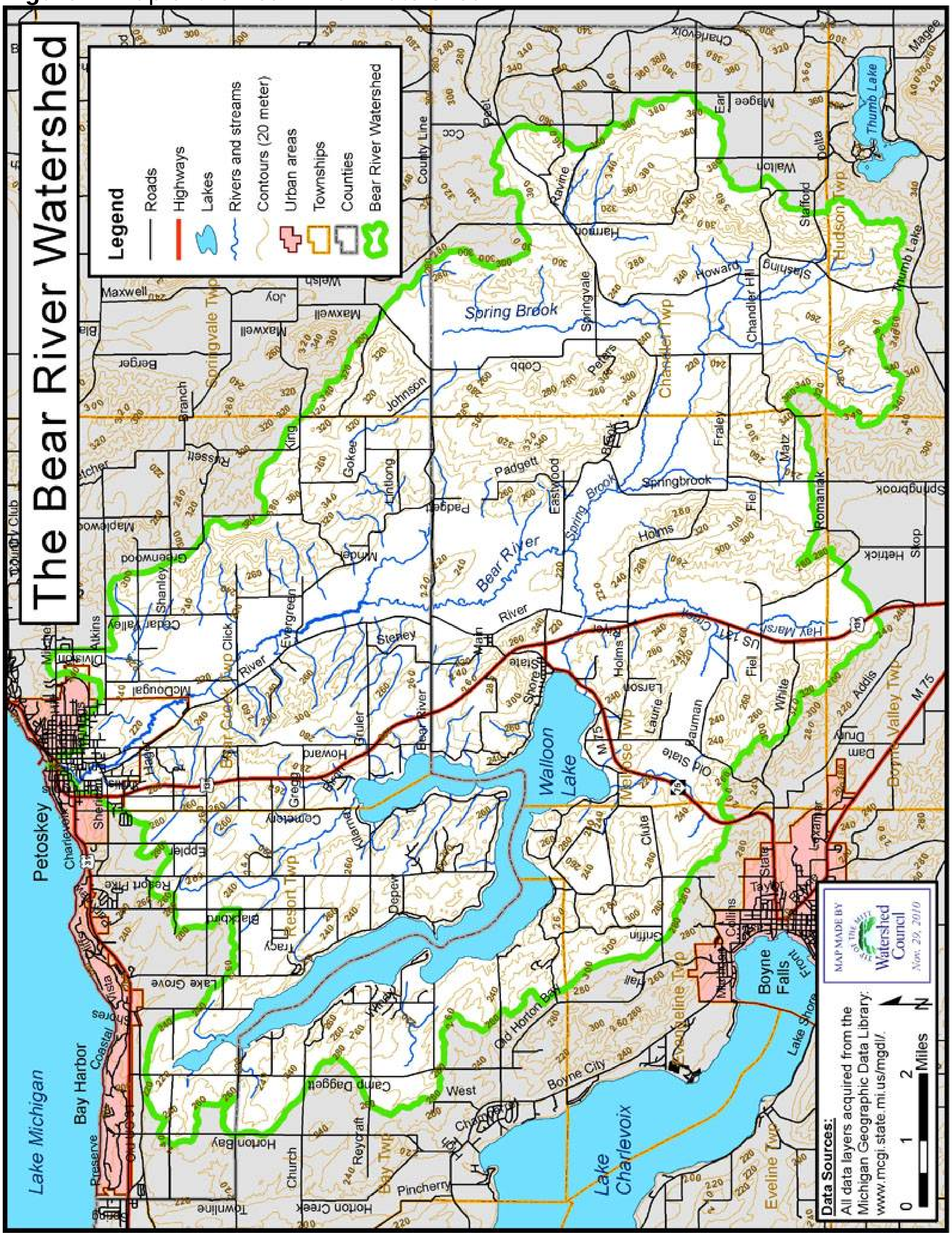
The Bear River Watershed drains approximately 74,215 acres of land and water in Emmet and Charlevoix Counties. The watershed includes land in Bear Creek, Resort, and Springvale Townships of Emmet County and in Bay, Boyne Valley, Chandler, Evangeline, Hudson and Melrose Townships of Charlevoix County. Based on 2006 remote sensing data from the Coastal Great Lakes Land Cover project, landcover in the watershed is mostly natural with 49% forested and 18% wetland (Table 1). Agricultural and urban landcover account for 18% of the watershed area.

Table 1. Bear River Watershed land-cover statistics.

Land Cover Type	2000 Acreage*	2000 Percent*	2006 Acreage*	2006 Percent*	Change (%)
Agriculture	10199.96	13.73	10625.43	14.31	0.57
Barren	157.79	0.21	169.06	0.23	0.02
Forested	35557.38	47.88	36213.36	48.76	0.88
Grassland	7314.87	9.85	4629.60	6.23	-3.62
Scrub/shrub	1410.95	1.90	1645.73	2.22	0.32
Urban	2045.96	2.76	2821.68	3.80	1.04
Water	4823.54	6.50	4727.00	6.37	-0.13
Wetland	12752.60	17.17	13431.20	18.09	0.91
TOTAL	74263.05	100.00	74263.05	100.00	NA

**Land-cover data from the NOAA Coastal Change Analysis Program.*

Figure 1. Map of the Bear River Watershed.



WATER QUALITY OF THE BEAR RIVER

Nearly 40 years of water quality data from the Bear River Watershed show that there have been some changes, but that water quality and the stream ecosystem are in relatively good shape. This is not surprising because the Bear River Watershed remains relatively undeveloped; recent landcover data (2006) showing that agricultural and urban landcover comprise a low percentage of total landcover in the watershed (14% and 4% respectively). Furthermore, the high quality water of Walloon Lake supplies water for and essentially forms the main channel of the river. These factors contribute to the high quality of the Bear River evidenced in the water quality data.

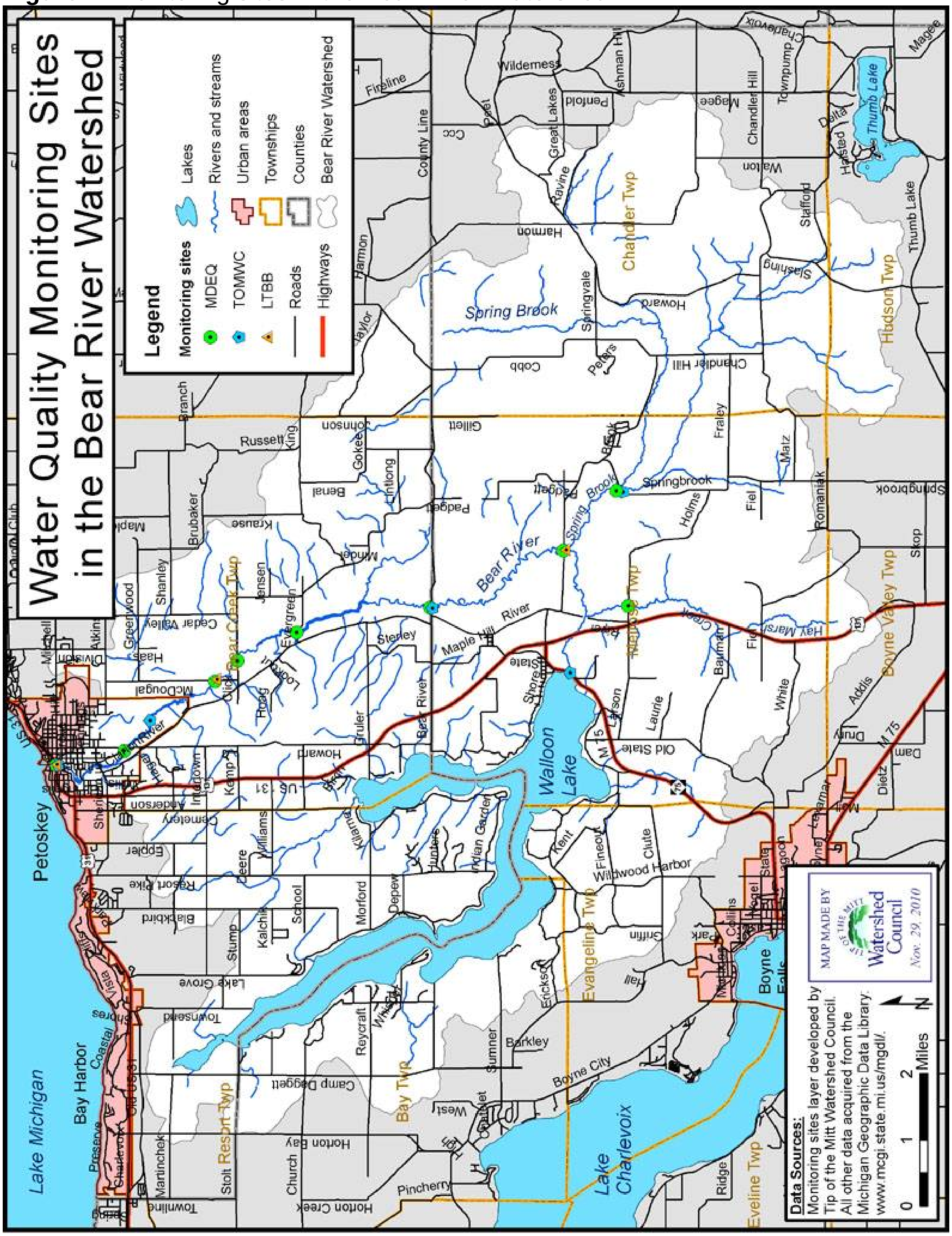
MDEQ and Legacy water quality data span four decades, stretching back to 1971 at some sites and collected at approximately 9 locations in the Bear River Watershed (Figure 2). TOMWC staff and volunteers have monitored water quality of the Bear River and its tributaries since 2006, with 3 sites on the Bear River, one site on Spring Brook, and one site on Russian Creek. LTBB staff monitor water quality at three sites on the Bear River; data going back to 2000.

In the following section, water quality data compiled from the Bear River are used to assess water quality and stream ecosystem health of the entire watershed, at individual sites, and relative to other rivers and streams. Depending upon the data type (e.g., chemical versus biological data) and parameter, water quality data are discussed in terms of ranges, averages, compliance with State of Michigan water quality standards, or comparisons to other sites within or outside the watershed.

Alkalinity and pH

Typical for water bodies in the Northern Lower Peninsula, the Bear River contains moderately hard water; with alkalinities ranging from 132 mg/l (milligrams per liter, which equals parts per million) to 175 mg/l $CaCO_3$. The river's pH levels have ranged from 7.11 to 8.78, complying with State standards that require pH to be maintained within a range of 6.5 to 9.0.

Figure 2. Monitoring sites in the Bear River Watershed.



Dissolved Oxygen

Dissolved oxygen is one of the most important parameters monitored for assessing water quality. Oxygen is required by almost all organisms, including those that live in the water. Oxygen dissolves into the water from the atmosphere and through photosynthesis of aquatic plants and algae. MDEQ water quality standards require that a minimum of 5 to 5 parts per million (PPM) be maintained at all times in inland streams. The higher standard of 7 PPM applies to waters designated as supporting a cold-water fishery. The Bear River contains a mixed cold and warm-water fishery.

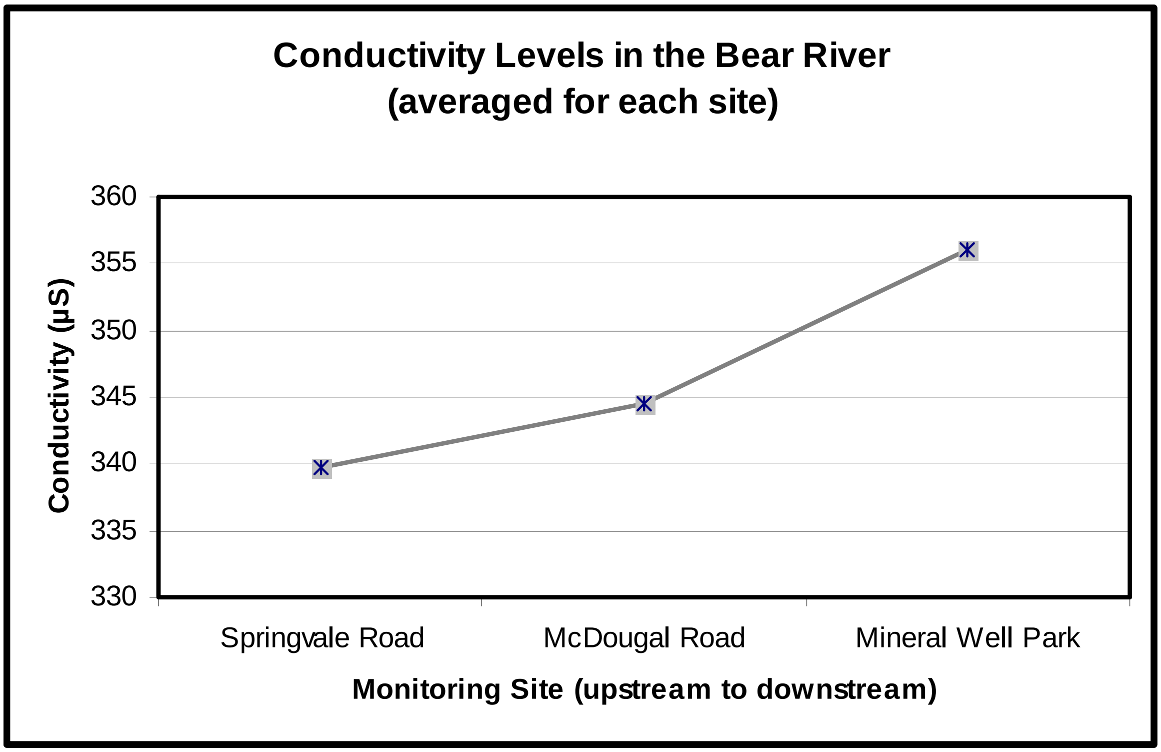
In terms of dissolved oxygen readings, the LTBB water quality dataset is the most extensive; including 94 separate readings at three locations and over the course of 10 years. Data from the tribe show that dissolved oxygen levels in the Bear River have ranged from a low of 5.95 PPM (McDougal Road, 6-19-2002) to a high of 15.28 PPM (Mineral Well Park, 2-18-2010). Dissolved oxygen data from MDEQ and TOMWC also fall within this range. Readings below 7 PPM have only been recorded 4 times and all occurred at the McDougal Road crossing. In general, data indicate that dissolved oxygen is abundant year-round throughout the river system.

Conductivity and Chloride

Conductivity is a measure of the ability of water to conduct an electric current, which is dependent upon the concentration of charged particles (ions) dissolved in the water. Chloride, a component of salt, is a negatively charged particle that contributes to the conductivity of water. Chloride is a "mobile ion," meaning it is not removed by chemical or biological processes in soil or water. Many products associated with human activities contain chloride (e.g., de-icing salts, water softener salts, and bleach).   Conductivity and chloride levels in lakes and streams tend to increase as population and human activity in a watershed increase. Research shows that both conductivity and chloride levels in surface waters are good indicators of human disturbance in a watershed, particularly from urban landuse, (Jones and Clark 1987, Lenat and Crawford 1992, Herlihy et al. 1988).

LTBB water quality data show that conductivity levels in the Bear River, measured in microSiemens (µS), have ranged from 247 (LTBB, McDougal, 2004) to 412 (LTBB, Mineral Well Park, 2008). Averaged data for each site monitored by the tribe show that conductivity levels increase in a downstream direction (Figure 3). This increase could be caused by humans, but could also be a natural increase due to groundwater inputs with high conductivity.

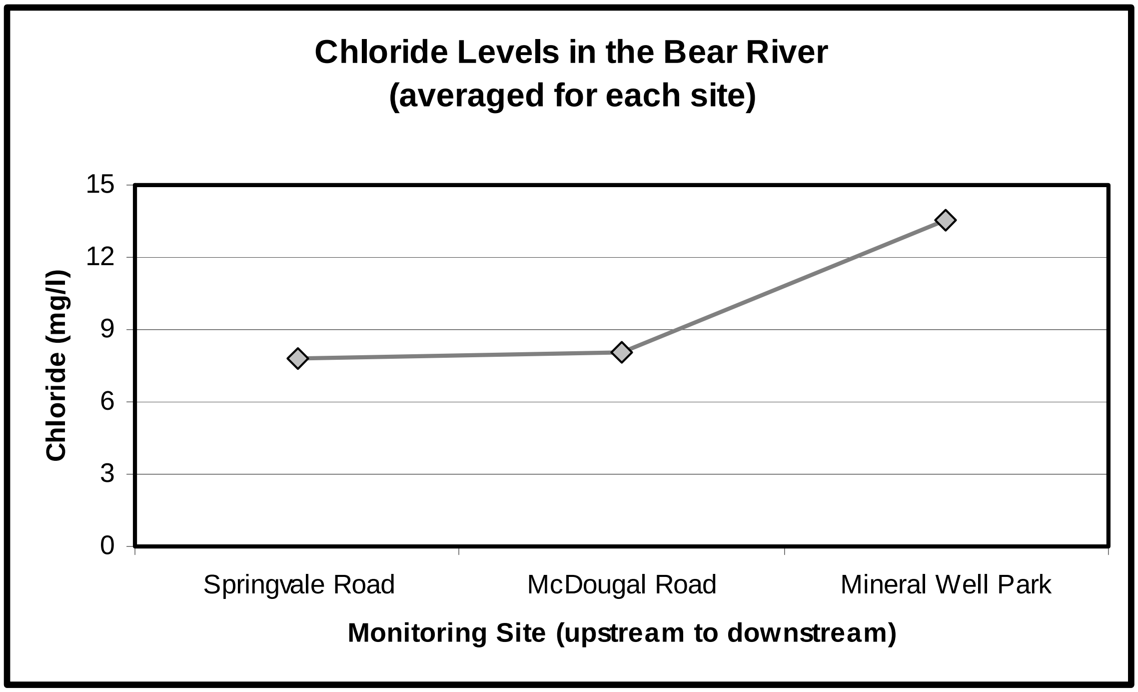
Figure 3. Conductivity levels in the Bear River.



Most conductivity data from MDEQ and TOMWC fall within the range documented by the Tribe. The exception is Russian Creek, a small tributary of the Bear River draining the North Central Michigan College property, where conductivity levels in excess of 600 µS have been recorded. The source of the high conductivity has not been determined, but stormwater runoff from the college campus or from nearby agricultural fields is suspected.

Chloride concentrations in the Bear River have ranged from 4.9 mg/l (McDougal Road, 2006) to 35.1 (Mineral Well Park, 2008). Similar to conductivity, averaged data for each site monitored by the tribe show that chloride levels increase in a downstream direction (Figure 4). Additionally, averaged yearly data at the Mineral Well Park site near the mouth of the river show that chloride concentrations have increased over time (Figure 5).

Figure 4. Chloride levels in the Bear River.



The increased chloride levels in the Bear River correspond with US Census data that show a steady population increase in counties in the Watershed between 1970 and 2000 (Table 2). Nonpoint source pollution in the Watershed, particularly from urban areas (i.e., Petoskey and Walloon Lake Village), is likely responsible for the increase. Although averaged chloride concentrations doubled, they are still far below levels that affect aquatic organisms. Studies show that chloride levels do not affect aquatic insects until well over 1,000 mg/l (Crowther and Hynes 1977, Blasius and Merritt 2002). However, increases in chloride can be indicative of more harmful pollutants associated with human activity (such as automotive fluids and metals from roads or nutrients/bacteria from septic systems) contaminating the Watershed's surface waters.

Figure 5. Chloride trends in the Bear River at Mineral Well Park.

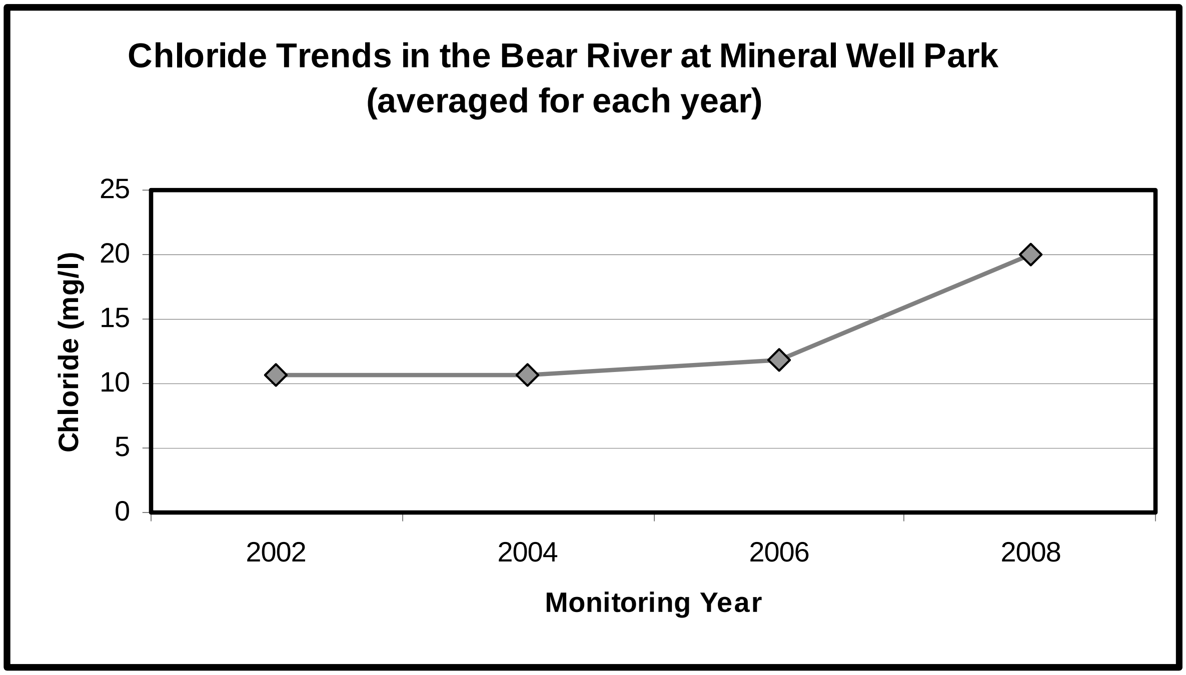


Table 2. Population trends for Emmet and Charlevoix Counties

County	Area (miles²)	1970 Population*	1970 Density (people/mile²)	1980 Population*	1980 Density (people/mile²)
Charlevoix	458.38	16,541	36	19,907	43
Emmet	486.74	18,331	38	22,992	47
Total		**34,872**		**42,899**	
County	**Area (miles²)**	**1990 Population***	**1990 Density (people/mile²)**	**2000 Population***	**2000 Density (people/mile²)**
	(miles²)	Population	(people/mile²)	Population	(people/mile²)
Charlevoix	458.38	21,468	47	26,090	57
Emmet	486.74	25,040	51	31,437	65
Total		**46,508**		**57,527**	

**Data from U.S. Census Bureau*

Nutrients

Nutrients are chemicals needed by organisms to live, grow, and reproduce. Nutrients occur naturally and can be found in soils, water, air, plants, and animals. Phosphorus and nitrogen are essential nutrients for plant growth and important for maintaining healthy, vibrant aquatic ecosystems. However, excess nutrients from sources such as fertilizers, faulty septic systems, and stormwater runoff lead to nutrient pollution, which can have negative impacts on the Bear River and its tributaries.

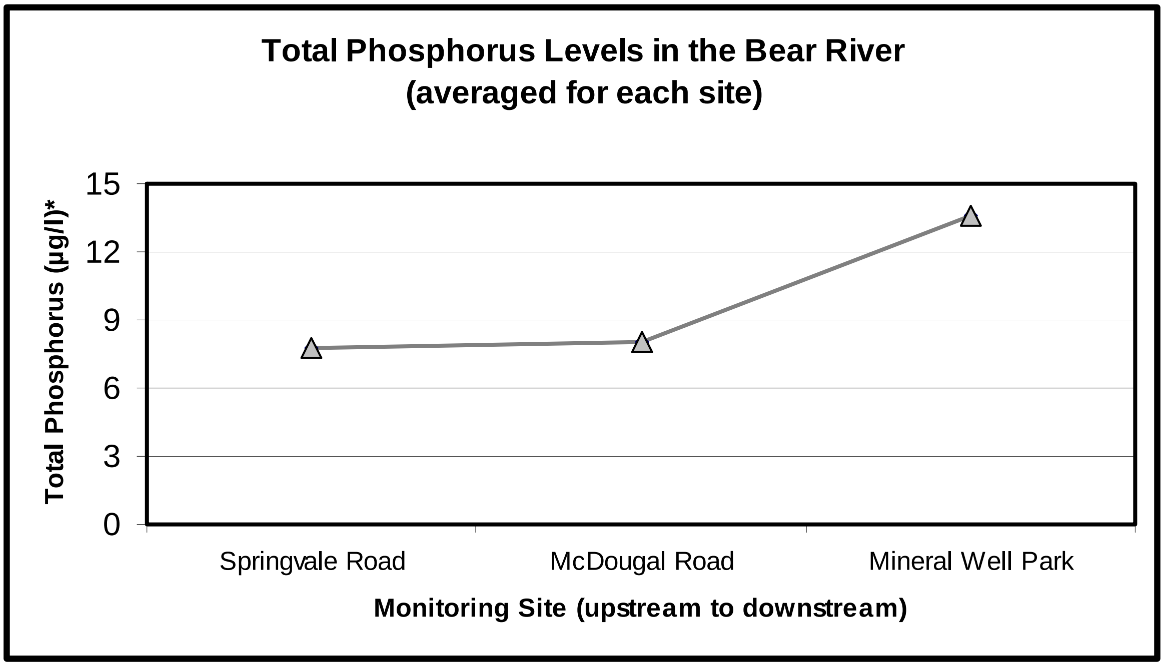
Phosphorus is the most important nutrient for plant productivity in Northern Michigan lakes and streams because it is usually in shortest supply relative to nitrogen and carbon. A water body is considered phosphorus limited if the ratio of nitrogen to phosphorus is greater than 15:1. Based on data collected by TOMWC, most lakes and streams monitored in the Northern Lower Peninsula, including the Bear River, are found to be phosphorus limited. It has been estimated that one pound of phosphorus could stimulate 500 or more pounds of algae growth. Therefore, heavy phosphorus inputs into the Bear River could result in nuisance algae and plant growth, which could, in turn, degrade water quality and alter the natural stream ecosystem.

Because of the negative impacts that phosphorus can have on surface waters, legislation has been passed in Michigan to ban phosphorus in soaps and detergents and currently there is an effort underway to regulate phosphorus use in fertilizers. Water quality standards for nutrients in surface waters have not been established, though the U.S. EPA recommends that total phosphorus concentrations in streams discharging into lakes not exceed 50 parts per billion PPB). Data collected by LTBB, TOMWC, and MDEQ show that total phosphorus concentrations in the Bear River have consistently been below 50 PPB and have rarely exceeded 20 PPB. As was the case with conductivity and chloride, LTBB data show that total phosphorus concentrations increase in a downstream direction (Figure 6).

Nitrogen is a very abundant element throughout the earth's surface and is a major component of all plant and animal matter. Nitrogen is also generally abundant in our lakes and streams and needed for plant and algae growth. Interestingly, algae have adapted to a wide variety of nitrogen situations in the aquatic environment, some fixing nitrogen directly from the atmosphere to compete in low-nitrogen environments (blue-green algae), while others tend to thrive in nitrogen-rich environments (certain diatoms).

Many different forms of nitrogen have been monitored in Bear River, of which two are here presented: total nitrogen and nitrate-nitrogen. Total nitrogen includes all organic and inorganic forms and is important in determining whether

Figure 6. Total phosphorus levels in the Bear River.

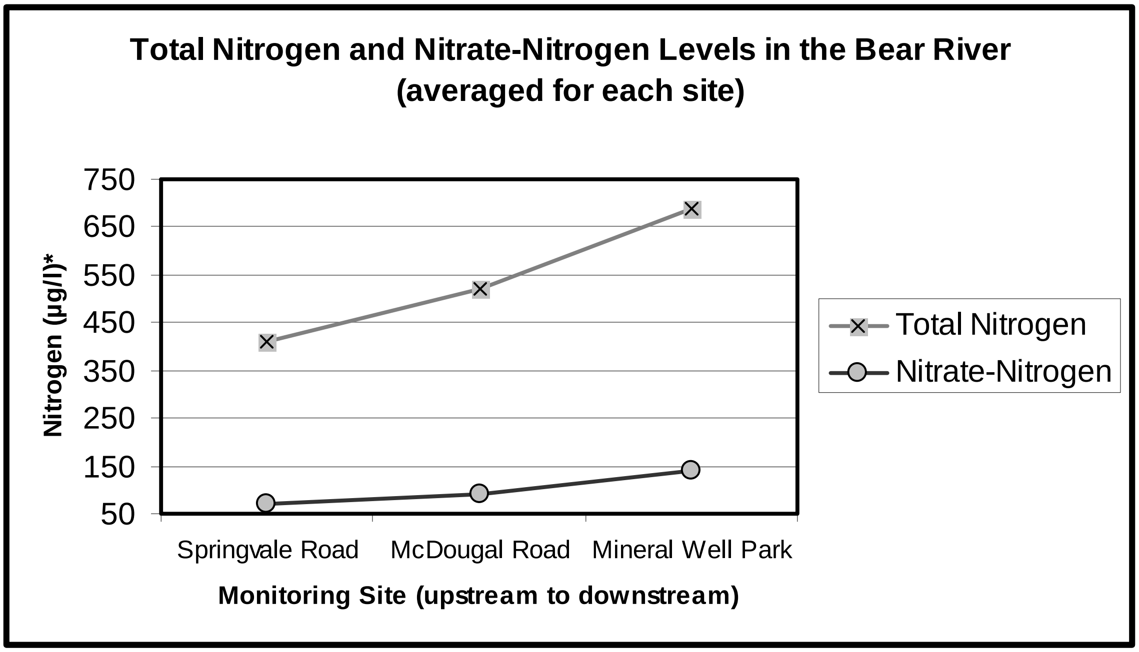


ug/l = micrograms/liter = parts per billion.

a lake is nitrogen limited in relation to phosphorus. Nitrate-nitrogen is soluble in water and readily available for uptake by aquatic plants and algae. Similar to phosphorus, surface water quality standards for nitrogen have not been set. However, Michigan drinking water standards require that nitrate-nitrogen concentrations be less than 10 PPM (=1,000 PPB).

Total nitrogen data for the Bear River show that levels have ranged from a low of 200 PPB (Springvale Road) to a high of 1,680 PPB (Mineral Well Park), while nitrate-nitrogen ranged from a low of 10 PPB (Springvale Road) to a high of 640 PPB (Springvale Road). All data were within typical ranges for streams of Northern Michigan and nitrate-nitrogen levels have consistently been below the drinking water standard. As with total phosphorus, LTBB data show that both total nitrogen and nitrate-nitrogen increase in a downstream direction (Figure 7).

Figure 7. Total nitrogen and nitrate-nitrogen levels in the Bear River.



**ug/l = micrograms/liter = parts per billion.*

<u>Heavy Metals</u>

Heavy metals are a loosely defined group of elements that have some metallic properties. Some of these metals, such as copper and zinc, are required in trace amounts by humans and other organisms, but can be harmful if excessive. Other heavy metals, such as lead and mercury, are not needed by organisms, but rather bio-accumulate in the bodies of and potentially harm fish, humans, and other animals. Another group of metals, including cadmium, are normally toxic, but do provide some benefit to certain organisms. Heavy metals occur naturally in the earth's crust and are used by humans in many applications. Degradation of products containing metals (e.g., cars), wastes from processing (e.g., factories), and by-products of industry (e.g., coal-burning energy plants) invariably cause some degree of environmental pollution, particularly in heavily populated areas.

Heavy metals are included in Michigan's water quality standards to address environmental problems and human health issues. Standards have been established for both surface waters to protect wildlife and for drinking water to protect human health. A list of these contaminants and limits established by the State of Michigan are available on the MDEQ web site.

Limited data are available for heavy metals in the Bear River; collected only by the MDEQ and on just three occasions. Water samples were analyzed for heavy metals twice at Lake Street (in 1971 and 1993) and once at McDougal Road (1976). MDEQ data include results for the following metals: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, titanium, vanadium, and zinc. Water samples were also analyzed for cyanide, another non-metallic contaminant of concern.

Most heavy metal concentrations were well below non-drinking and drinking water standards established by the State of Michigan. Cadmium did exceed the drinking water standard of 2.5 µg/l at Lake St in 1971, with a test value of 5 µg/l, though it was still well below the non-drinking water standard of 120 µg/l. Mercury was found at Lake Street at 0.20 µg/l, which was well over the drinking and non-drinking water standard of 0.0018 µg/l, as well as the wildlife value standard of 0.0013 µg/l. Mercury is a metal of special concern because of bioaccumulation, particularly in fish. A general fish consumption advisory has been issued by MDEQ and the Michigan Department of Community Health for all of Michigan's inland lakes due to monitoring results finding high levels of mercury in many of the lakes tested.

Biological Monitoring

The MDEQ, TOMWC, and LTBB have conducted biological monitoring of aquatic macroinvertebrate populations in the Bear River and its tributaries. The MDEQ monitored four sites in the watershed in 1993, one site in 1998, one site in 2003, and four sites in 2008. TOMWC volunteers in the Tip of the Mitt Volunteer Stream Monitoring Program monitor five sites in the Bear River Watershed, the earliest data going back to 2006. LTBB collects aquatic macroinvertebrate data at three locations in the watershed and has data from 2002, 2004, and 2006.

Biological monitoring methods used by MDEQ and TOMWC are similar in that a stream reach is sampled thoroughly, yet rapidly, with the goal of documenting the total aquatic macroinvertebrate diversity present at the site. Both MDEQ and TOMWC identify the macroinvertebrates to the family level. The LTBB program varies from the others in that biological monitoring is limited to specific habitats within the stream reach; often riffles, but sometimes combining different habitat types. Furthermore, LTBB identifies the aquatic macroinvertebrates to a lower taxonomic level (genus). Due to differences in methodologies, only biological data from MDEQ and TOMWC were used in this report.

The biological data from MDEQ and TOMWC were compiled and standardized to allow for comparisons between sites and among the differing datasets. Based on indices used in the TOMWC program, stream ecosystem health at a specific site was determined using three different measurements of diversity: 1) **total taxa**: the total number of macroinvertebrate families found at the site; 2) **EPT taxa**: the number of families in the most sensitive insect orders (Ephemeroptera=mayflies, Plecoptera=stoneflies, and Trichoptera=caddisflies); and 3) **sensitive taxa**: the number of families that are very sensitive to non-point source pollution as determined by William Hilsenhoff, PhD. These indices are used in the following section to present findings from each monitoring site. Scores for each stream are averaged using data from all monitoring events at that site and presented using the following format: (total, EPT, sensitive). For example, a site with a score of (20, 10, 5), means that it had an average of 20 total families, 10 EPT families, and 5 sensitive families.

In the headwater tributaries of the Bear River, the MDEQ has performed biological monitoring one time on Hay Marsh Creek (25, 5, 0) and one time on Spring Brook (25, 8, 4). TOMWC volunteers also monitor a site on Spring Brook (20,10, 4). Biotic index results for Spring Brook from MDEQ and TOMWC are similar; showing a diverse macroinvertebrate community with many sensitive families and indicating that the stream ecosystem is healthy. The total diversity at Hay Marsh Creek was similar to that of Spring Brook, but there were fewer EPT families, and none of the most sensitive macroinvertebrates. The disparity in index scores reflects the difference between Hay Marsh Creek and Spring Brook. The site monitored on Hay Marsh Creek is wide, slow, and exposed (i.e., marshy), with much less variety of habitat, and probably with warmer waters. Conversely, sites monitored on Spring Brook have faster flows, a good variety of habitat, are well-shaded from dense vegetation, and probably with cooler waters as a result of shade and groundwater inputs.

In the Upper Bear River Watershed, biological monitoring has been conducted at Melrose Township Park in Walloon Lake Village, Springvale Road, County Line Road, and Evergreen Road. TOMWC volunteers have monitored Melrose Township Park from 2007 to 2010 (17, 4, 2). Springvale Road was monitored one time by MDEQ in 1993 (18, 4, 3). County Line Road (AKA, Bear River Road) has been monitored by TOMWC since 2006 (20, 9, 4) and one time by MDEQ in 1998 (31, 10, 4). Evergreen Road was monitored one time by MDEQ in 2008 (29, 6, 3).

Total family and EPT diversity scores vary considerably between sites in the Upper Bear River Watershed, though sensitive family diversity is fairly similar. The low scores recorded at Melrose Township Park are probably the result of warm water that drains from the surface of Walloon Lake (warm water holds less dissolved oxygen than cold water), stormwater drainage from the road, and habitat degradation from the removal of streamside vegetation in the park. The variety of in-stream habitat and faster flows found at County Line Road likely contribute to the high diversity scores recorded at the site. Overall, results indicate that stream ecosystem is healthy in the Upper Bear River Watershed.

In the Lower Bear River Watershed, biological monitoring has been carried out at Click Road, Russian Creek, Howard Street and US31 in Petoskey. MDEQ monitored Click Road one time in 2008 (31, 11, 4). Russian Creek, a small tributary of the Bear draining North Central Michigan College property, has been monitored since 2008 (14, 5, 2). Howard Street was monitored by MDEQ in 1993 and again in 2008 (20, 7, 4). The US31 site in Petoskey was monitored once by MDEQ in 1993 (19, 9, 4) and from 2006 to 2010 by TOMWC volunteers (15, 6, 3).

Biological monitoring of the Lower Bear River Watershed indicates that the stream ecosystem remains intact, though perhaps less healthy in the downstream section near the mouth. Aquatic macroinvertebrate diversity at the Click Road site is comparable to sites upstream at Evergreen and County Line Roads. However, there is a marked decrease in total family diversity at the US31 site, which may reflect impacts from the surrounding urban area of Petoskey.

The low diversity index scores from Russian Creek, relative to those in the main stem of the Bear River, may simply be a function of stream size, but could also be the result of anthropogenic disturbance.

Relative to other rivers and streams in Northern Michigan, the Bear River has moderate to high aquatic macroinvertebrate diversity. Biological data from other streams monitored as part of the TOMWC volunteer program show a range of macroinvertebrate diversity found in the region (Table 3). Streams that suffer from the negative impacts of urbanization, such as Stover and Tannery Creeks, have lower diversity scores than the Bear River, while pristine high quality trout streams like the Boyne and Jordan Rivers have somewhat higher diversity scores. Thus, water quality of the Bear River falls somewhere in the middle; with diversity scores at some sites approaching those of high quality trout streams, but none as low as heavily impacted sites on urbanized streams.

Table 3. Biological data from the Bear River and other streams.

Stream	Location	Total Families	EPT Families	Sensitive Families
Bear River	Melrose Twp Park	17	4	2
Bear River	County Line Road	20	10	4
Bear River	US31, Petoskey	15	6	3
Boyne River	Dam Road	19	10	5
Jordan River	Webster Road	20	12	7
Stover Creek	Mouth, Irish Boat Shop	14	2	0
Tannery Creek	Mouth, Glens Plaza	12	3	1

In general, biological data show that the Bear River ecosystem is healthy; with diverse aquatic macroinvertebrate communities throughout most of the watershed. Total family and EPT diversity vary from site to site with higher numbers in the mid watershed, but sensitive family diversity is fairly consistent throughout. Lower diversity scores are probably due to natural circumstances at some sites, such as Hay Marsh Creek, but may reflect human impacts at other sites, such as the US31 site in Petoskey.

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Appendix 1. Parameters monitored in the Bear River Watershed.

Parameter	MDEQ	TOMWC	LTBB	Parameter	MDEQ	TOMWC	LTBB
Physico-Chemical				Selenium	Yes	No	No
Alkalinity, bicarbonate	Yes	No	No	Silicate, total	Yes	No	No
Alkalinity, carbonate	Yes	No	No	Silver, dissolved	Yes	No	No
Alkalinity (as CaCO3)	Yes	No	No	Sodium, dissolved	Yes	No	No
Ammonia	Yes	No	No	Solids, total dissolved	Yes	No	Yes
Antimony	Yes	No	No	Solids, total suspended	Yes	No	No
Arsenic, dissolved	Yes	No	No	Sulfate	Yes	No	No
Barium, total	Yes	No	No	Temperature, water	Yes	Yes	Yes
Beryllium, total	Yes	No	No	Titanium	Yes	No	No
BOD (biological oxygen demand)	Yes	No	No	Turbidity	Yes	No	Yes
Cadmium, dissolved	Yes	No	No	Vanadium	Yes	No	No
Calcium, total	Yes	No	No	Zinc, dissolved	Yes	No	No
Carbon, total Organic	Yes	No	No	**Habitat**			
Chloride	Yes	Yes	Yes	Weather	Yes	Yes	Yes
Chlorophyll-a	Yes	No	Yes	Air Temperature (°F)	Yes	Yes	Yes
Chromium, Hexavalent	Yes	No	No	Water Temperature (°F)	Yes	Yes	Yes
Cobalt, total	Yes	No	No	Avg Stream Width (ft)	Yes	Yes	Yes
COD (chemical oxygen demand)	Yes	No	No	Avg Stream Depth (ft)	Yes	Yes	Yes
Coliforms, total	Yes	No	No	Surface Velocity (ft/s)	Yes	Yes	Yes
Conductivity	Yes	Yes	Yes	Estimated Flow (cfs)	Yes	Yes	Yes
Copper, dissolved	Yes	No	No	Stream Modifications	Yes	Yes	No
Cyanide	Yes	No	No	Nuisance Plants (Y/N)	Yes	No	No
Fecal Coliform	Yes	No	No	Epifaunal Substrate & Cover	Yes	No	No
Fecal Streptococci	Yes	No	No	Embeddedness	Yes	Yes	No
Flouride, dissolved	Yes	No	No	Velocity/Depth Regime	Yes	Yes	Yes
Hardness, calculated	Yes	No	No	Pool Substrate Characterization	Yes	No	No
Iron, dissolved	Yes	No	No	Pool Variability	Yes	No	No
Lead, dissolved	Yes	No	No	Sediment Deposition	Yes	Yes	No
Lithium, total	Yes	No	No	Flow Status Maintaining Flow Vol	Yes	No	No
Magnesium, total	Yes	No	No	Flow Status Flashiness	Yes	No	No
Manganese, total	Yes	No	No	Channel Alteration	Yes	Yes	No
Mercury, total	Yes	No	No	Frequency of Riffles/Bends	Yes	Yes	No
Molybdenum, total	Yes	No	No	Channel Sinuosity	Yes	Yes	No
Nickel, total	Yes	No	No	Bank Stability (L)	Yes	No	No
Nitrate + Nitrite	Yes	Yes	Yes	Bank Stability (R)	Yes	No	No
Nitrite	Yes	No	No	Vegetative Protection (L)	Yes	No	No
Nitrogen, total	Yes	Yes	Yes	Vegetative Protection (R)	Yes	No	No
Oxygen, dissolved	Yes	Yes	Yes	Riparian Veg Zone Width (L)	Yes	No	No
Oxygen, dissolved % saturation	Yes	No	No	Riparian Veg Zone Width (R)	Yes	No	No
pH	Yes	Yes	Yes	Habitat Rating	Yes	No	No
Phenolics, total	Yes	No	No	**Biological**			
Phosphorus, total	Yes	Yes	Yes	Diversity, total taxa	Yes	Yes	Yes
Phosphorus, soluble reactive	Yes	No	No	Diversity, EPT families	Yes	Yes	Yes
Potassium, dissolved	Yes	No	No	Diversity, sensitive families	Yes	Yes	Yes