3.0 Watershed Inventory 2 – Water Quality

To better understand the LCEB watershed, an assessment of existing water quality sampling studies was conducted. Reviewing past and current water quality is fundamental to developing a more complete understanding of the watershed. Because the LCEB is within the Great Lakes system, water quality standards under Indiana Administrative Code (IAC) 327 IAC 2-1.5 apply. The main stem of the LCEB and its tributaries, downstream to Lake Michigan via Burns Waterway, are designated as salmonid streams (327 IAC 2-1.5-5) for which more stringent water quality standards apply for some parameters.

3.1 Historic Water Quality Sampling Campaigns

Several water quality-sampling campaigns have been conducted in the LCEB watershed in recent history.

Impaired Waterbodies – 303(d)

As required by Chapter 305(b) of the Clean Water Act, the Indiana Department of Environmental Management is charged with assessing water quality in the state. Each water body is assigned a rating based on its ability to meet Indiana's Water Quality Standards, which were developed in an effort to make all Indiana waters swimmable, fishable and drinkable. Waterways that fail designated standards are declared impaired and put on the 303(d) listing.

Nearly all the stream segments within the LCEB watershed have been found to be impaired for *E. coli*, nutrients, biotic communities, dissolved oxygen, chloride and/or PCBs in fish tissue. In 2005, U.S. EPA approved a TMDL completed by IDEM to address the *E. coli* impairments in the Little Calumet River mainstem. Table 9 shows the impaired stream segments within the LCEB that were addressed by this TMDL. These segments continue to be impaired and remain on subsequent versions of the 303(d) list with an updated AUID under Category 4A. Additional impairments have been found in the watershed (using the updated AUIDs), but no new TMDLs have been completed (Table 10).

Table 10 shows the 303(d) listed stream segments within the LCEB watershed from the 2008 and 2010 approved listings, as well as the 2012 draft listing (see Figure 32). As of the writing of this report, the 2012 and 2014 impaired streams listings are in draft form and have not yet been approved by EPA.

In 2012, a baseline study of water chemistry and biotic communities in the watershed was performed by IDEM and National Parks Service (NPS) staff on a monthly basis at the 48 LCEB baseline sampling sites. As a result of this comprehensive sampling program, IDEM reassessed the stream segments in February 2013 and found additional impairments (Table 11 and Figure 33). Figures 34, 35 and 36 highlight the specific 2014 draft 303(d) impairments for stream reaches throughout the watershed.

Table 9. Impaired water bodies from the 2004 Little Calumet and Portage Burns Waterway TMDL for *E. coli* Bacteria

Subwatershed	Old AUID	New AUID	Assessment Unit Name	Cause of Impairment	Category	Year Listed
REYNOLDS	INC0161 _T1023	INC0141_ T1002	LITTLE CALUMET RIVER, EAST ARM, UNNAMED TRIBUTARY	E. COLI	4A	2006
REYNOLDS	INC0161 _T1023	INC0141_ 01	LITTLE CALUMET RIVER, EAST ARM	E. COLI	4A	2006
KEMPER	INC0162 _T1060	INC0142_ 01	LITTLE CALUMET RIVER, EAST ARM	E. COLI	4A	2006
KEMPER	INC0162 _T1082	INC0142_ 01	LITTLE CALUMET RIVER, EAST ARM	E. COLI	4A	2006
COFFEE	INC0163 _T1061	INC0143_ 04	LITTLE CALUMET RIVER, EAST ARM	E. COLI	4A	2006
COFFEE	INC0164 _T1018	INC0143_ 04	LITTLE CALUMET RIVER, EAST ARM	E. COLI	4A	2006
COFFEE	INC0164 _T1086	INC0143_ 04	LITTLE CALUMET RIVER, EAST ARM	E. COLI	4A	2006
COFFEE	INC0164 _T1108	INC0143_ 04	LITTLE CALUMET RIVER, EAST ARM	E. COLI	4A	2006

Table 10. 2008, 2010, and 2012 (draft) 303(d) listed streams

Subwatershed	AUID	Assessment Unit Name	Cause of Impairment	Category	Year Listed
KEMPER	INC0142_ T1003	LITTLE CALUMET RIVER, EAST ARM, UNNAMED TRIBUTARY	E. COLI	5A	2008, 2010, 2012
COFFEE	INC0143_ 04	LITTLE CALUMET RIVER, EAST ARM	IMPAIRED BIOTIC COMMUNITIES	5A	2008, 2010, 2012
COFFEE	INC0143_ 04	LITTLE CALUMET RIVER, EAST ARM	E. COLI	5A	2008
COFFEE	INC0143_ 04	LITTLE CALUMET RIVER, EAST ARM	PCBs (FISH TISSUE)	5B	2008, 2010, 2012
COFFEE	INC0143_ T1006	COFFEE CREEK	E. COLI	5A	2008, 2010, 2012
COFFEE	INC0143_ T1007	COFFEE CREEK, UNNAMED TRIBUTARY	E. COLI	5A	2010, 2012

Table 11. 2014 (draft) 303(d) listed streams

Subwatershed	AUID	AUID Name	Cause of Impairment	Category	Year Listed
REYNOLDS	INC0141_01	LITTLE CALUMET RIVER, EAST ARM	DISSOLVED OXYGEN	5A	2014
REYNOLDS	INC0141_01	LITTLE CALUMET RIVER, EAST ARM	IMPAIRED BIOTIC COMMUNITIES	5A	2014
REYNOLDS	INC0141_T1001	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	DISSOLVED OXYGEN	5A	2014
REYNOLDS	INC0141_T1002	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	IMPAIRED BIOTIC COMMUNITIES	5A	2014
REYNOLDS	INC0141_T1003	REYNOLDS CREEK	IMPAIRED BIOTIC COMMUNITIES	5A	2014
REYNOLDS	INC0141_T1004	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	IMPAIRED BIOTIC COMMUNITIES	5A	2014
REYNOLDS	INC0141_T1004	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	E. COLI	5A	2014
COFFEE	INC0142_01	LITTLE CALUMET RIVER, EAST ARM	DISSOLVED OXYGEN	5A	2014
COFFEE	INC0142_01	LITTLE CALUMET RIVER, EAST ARM	IMPAIRED BIOTIC COMMUNITIES	5A	2014
COFFEE	INC0142_01	LITTLE CALUMET RIVER, EAST ARM	NUTRIENTS	5A	2014
COFFEE	INC0142_T1001	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	IMPAIRED BIOTIC COMMUNITIES	5A	2014
COFFEE	INC0142_T1001	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	NUTRIENTS	5A	2014
COFFEE	INC0142_T1001	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	E. COLI	5A	2014
COFFEE	INC0142_T1001	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	DISSOLVED OXYGEN	5A	2014
COFFEE	INC0142_T1002	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	IMPAIRED BIOTIC COMMUNITIES	5A	2014
COFFEE	INC0142_T1002	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	E. COLI	5A	2014
KEMPER	INC0142_T1003	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	E. COLI	5A	2014
KEMPER	INC0142_T1003	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	IMPAIRED BIOTIC COMMUNITIES	5A	2014

Subwatershed	AUID	AUID Name	Cause of Impairment	Category	Year Listed
KEMPER	INC0142 _T1004	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	NUTRIENTS	5A	2014
KEMPER	INC0142 _T1004	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	DISSOLVED OXYGEN	5A	2014
KEMPER	INC0142 _T1004	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	E. COLI	5A	2014
KEMPER	INC0142 _T1004	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	IMPAIRED BIOTIC COMMUNITIES	5A	2014
COFFEE	INC0143 _04	LITTLE CALUMET RIVER, EAST ARM	PCBS (FISH TISSUE)	5B	2014
COFFEE	INC0143 _04	LITTLE CALUMET RIVER, EAST ARM	IMPAIRED BIOTIC COMMUNITIES	5A	2014
COFFEE	INC0143 _T1002	WILLOW CREEK (UPSTREAM F CHRISMAN DITCH)	DISSOLVED OXYGEN	5A	2014
COFFEE	INC0143 _T1005	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	CHLORIDE	5A	2014
COFFEE	INC0143 _T1005	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	E. COLI	5A	2014
COFFEE	INC0143 _T1005	LITTLE CALUMET RIVER, EAST ARM - UNNAMED TRIBUTARY	IMPAIRED BIOTIC COMMUNITIES	5A	2014
COFFEE	INC0143 _T1006	COFFEE CREEK	IMPAIRED BIOTIC COMMUNITIES	5A	2014
COFFEE	INC0143 _T1006	COFFEE CREEK	DISSOLVED OXYGEN	5A	2014
COFFEE	INC0143 _T1006	COFFEE CREEK	E. COLI	5A	2014
COFFEE	INC0143 _T1007	COFFEE CREEK - UNNAMED TRIBUTARY	NUTRIENTS	5A	2014
COFFEE	INC0143 _T1007	COFFEE CREEK - UNNAMED TRIBUTARY	IMPAIRED BIOTIC COMMUNITIES	5A	2014
COFFEE	INC0143 _T1007	COFFEE CREEK - UNNAMED TRIBUTARY	DISSOLVED OXYGEN	5A	2014
COFFEE	INC0143 _T1007	COFFEE CREEK - UNNAMED TRIBUTARY	E. COLI	5A	2014
COFFEE	INC0143 _T1008	PETERSON DITCH	DISSOLVED OXYGEN	5A	2014
COFFEE	INC0143 _T1008	PETERSON DITCH	E. COLI	5A	2014
COFFEE	INC0143 _T1008	PETERSON DITCH	IMPAIRED BIOTIC COMMUNITIES	5A	2014

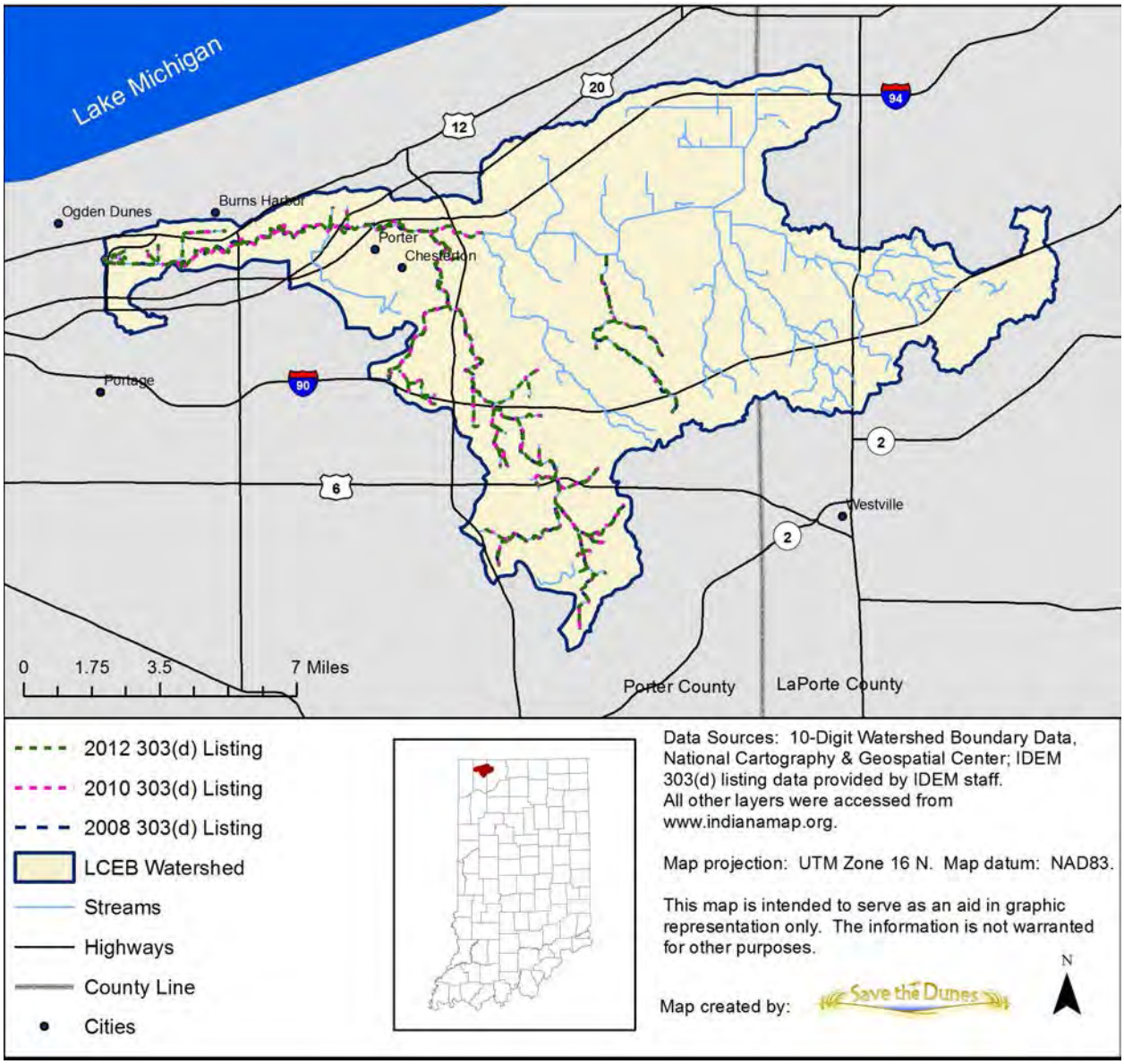

Figure 32. 2008, 2010, and 2012 303(d) listings

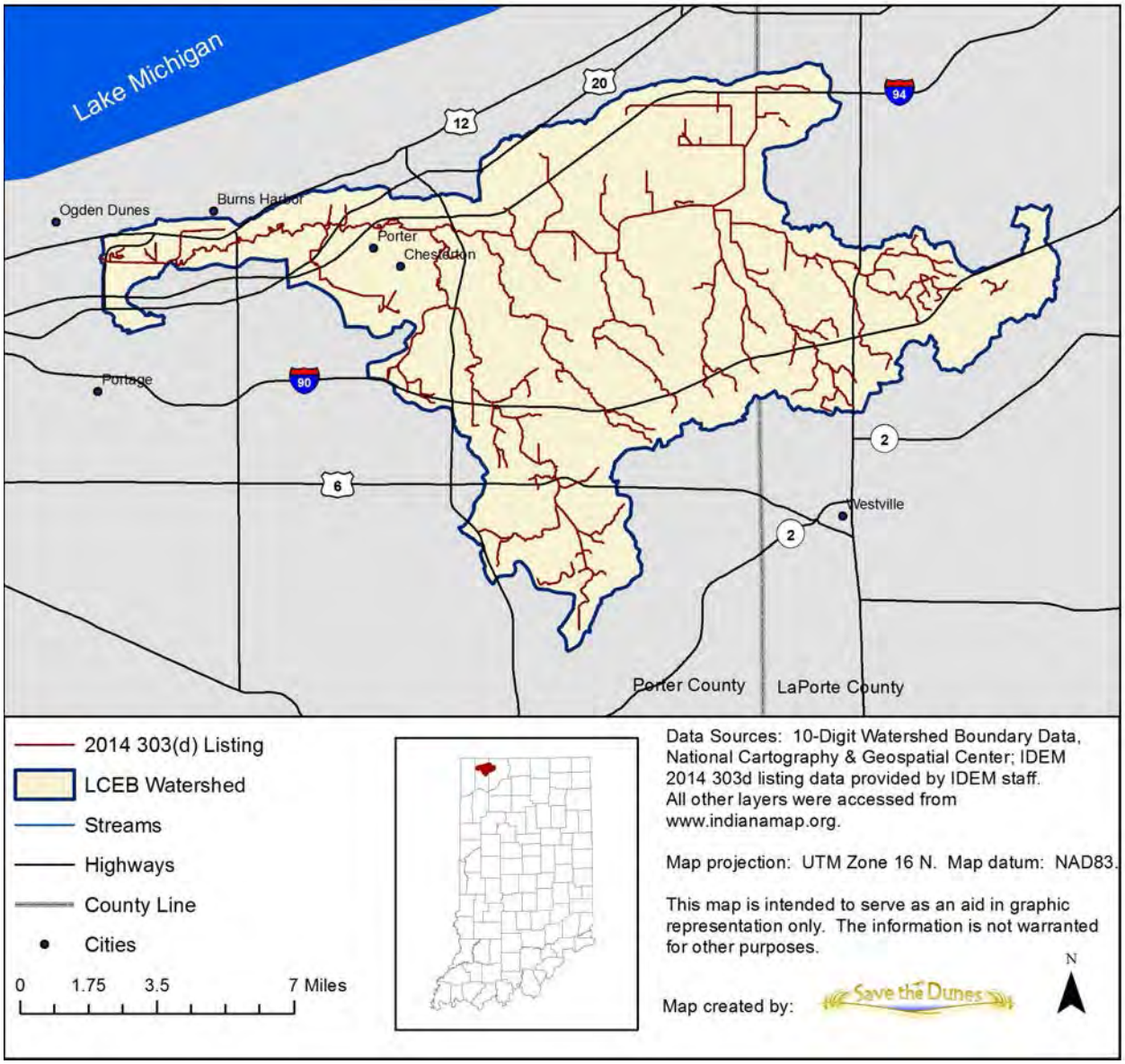

Figure 33. 2014 draft 303(d) listing

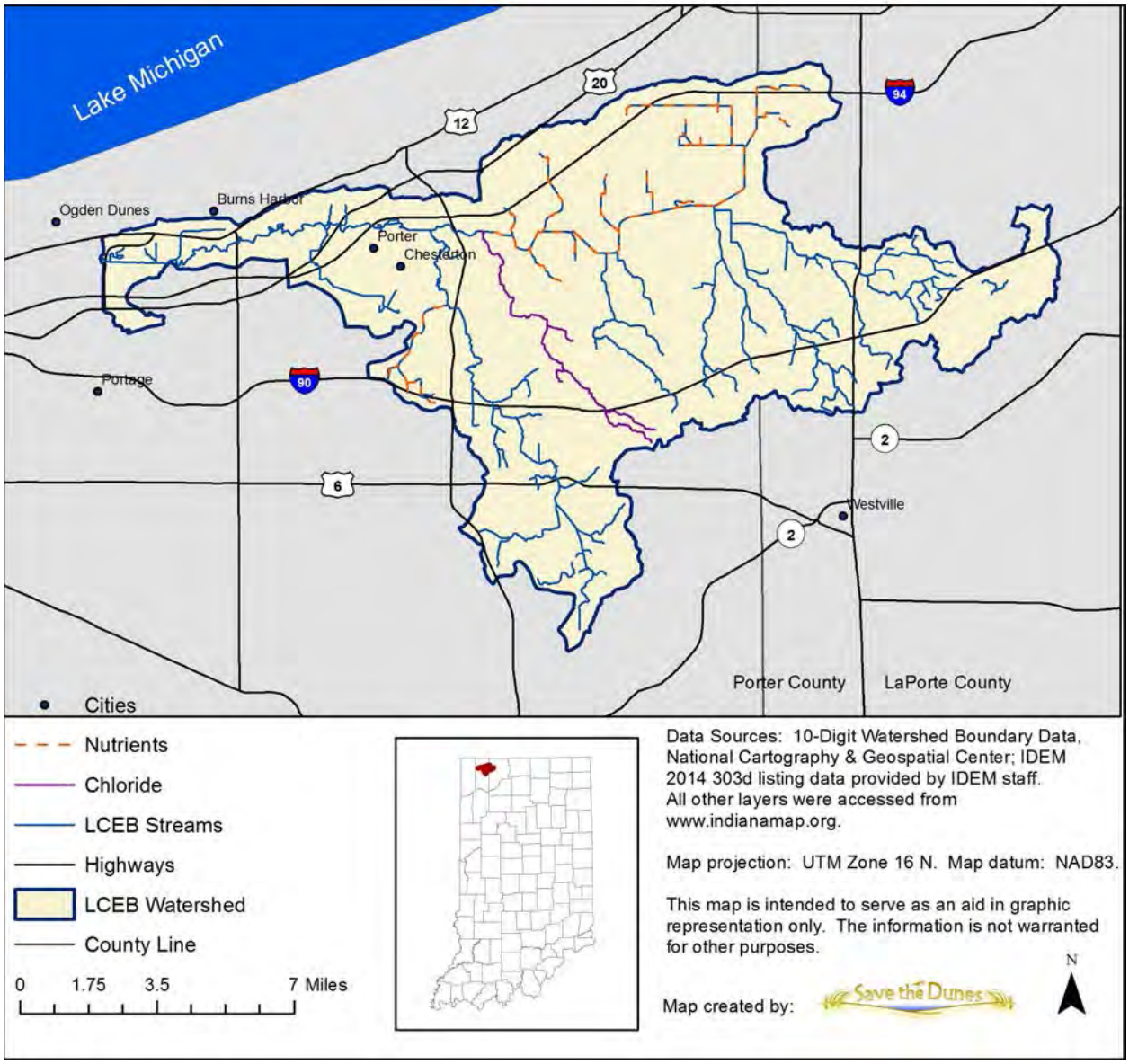

Figure 34. 2014 draft 303(d) listing for nutrients and chloride

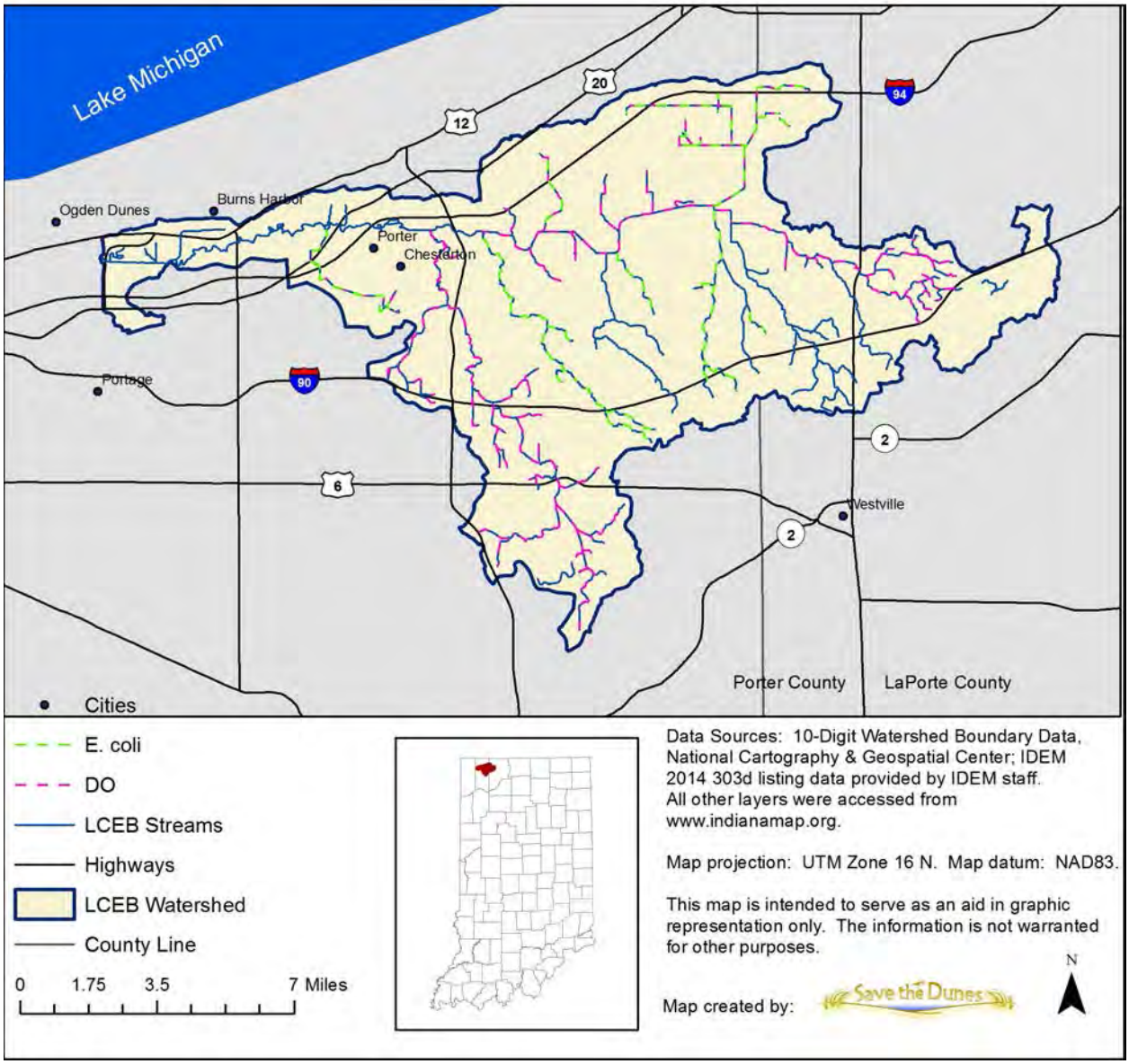

Figure 35. 2014 draft 303(d) listings for *E. coli* and dissolved oxygen (DO)

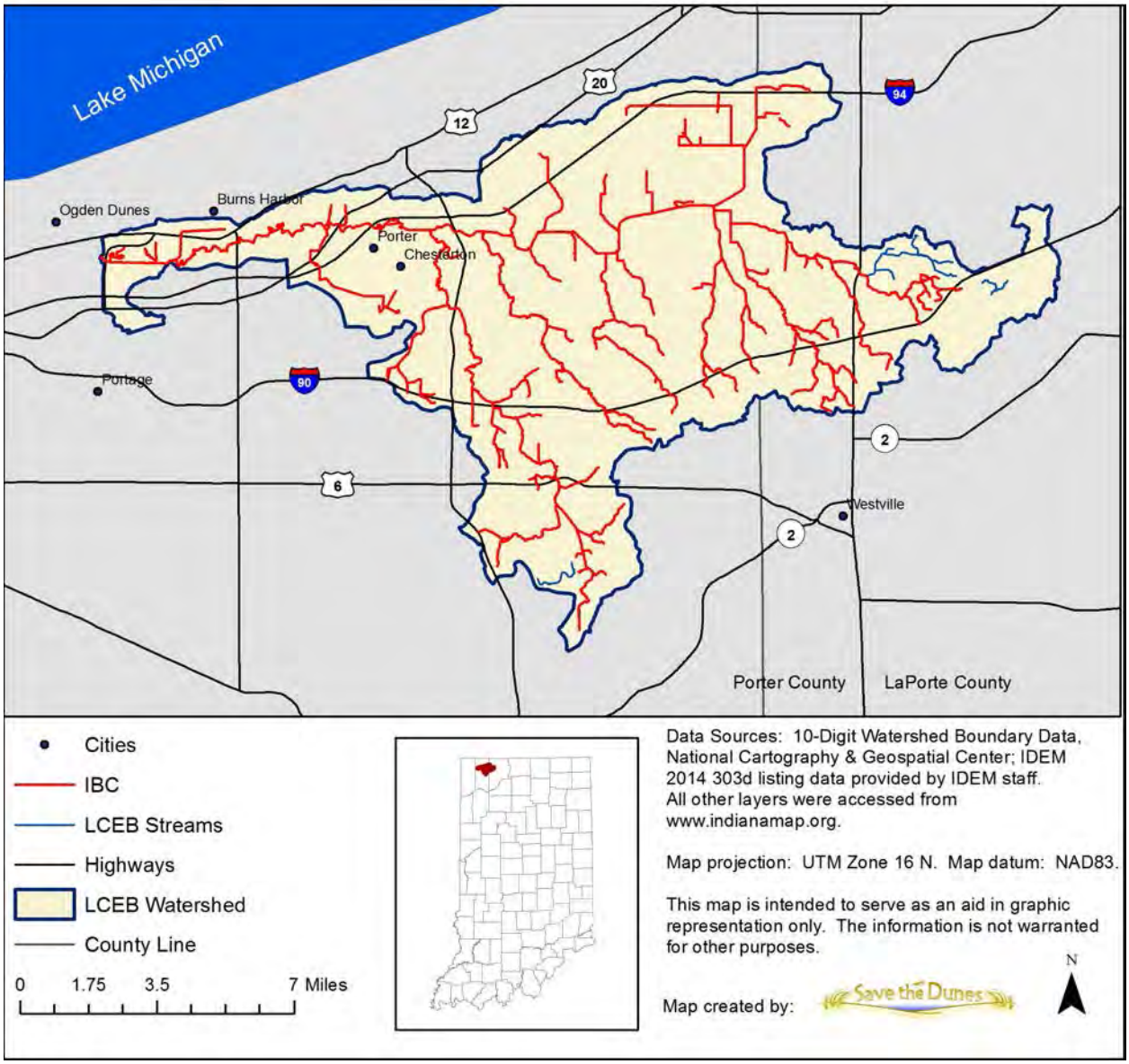

Figure 36. 2014 draft 303(d) listings for impaired biotic communities (IBC)

Fish Consumption Advisory

The Fish Consumption Advisory (FCA) is produced through collaboration with Indiana Department of Environmental Management, Indiana Department of Natural Resources, and Indiana State Department of Health. Fish tissue samples are collected on a rotating basin methodology and analyzed for PCBs, pesticides and heavy metals. The Fish Consumption Advisory listing in Table 12 is for the LCEB River in Porter and LaPorte Counties.

Advisory Groups for the Indiana Fish Consumption Advisory:

- Group 1: Unrestricted consumption for adult males and females. One meal per week for women who are pregnant or breastfeeding, women who plan to have children, and children under the age of 15.
- Group 2: Limit to one meal per week (52 meals per year) for adult males and females. One meal per month for women who are pregnant or breastfeeding, women who plan to have children, and children under the age of 15.
- Group 3: Limit to one meal per month (12 meals per year) for adult males and females. Women who are pregnant or breastfeeding, women who plan to have children, and children under the age of 15-Do Not Eat.
- Group 4: Limit to one meal every two months (6 meals per year) for adult males and females. Women who are pregnant or breastfeeding, women who plan to have children, and children under the age of 15-Do Not Eat.
- Group 5: No consumption (Do Not Eat).

Table 12. Fish Consumption Advisory listing for the LCEB watershed

Fish Species	Fish Size (inches)	Advisory Group
Black Buffalo	All	3
Bluegill	Up to 7	1
Channel Catfish	All	4
Common Carp	Up to 22	3
Common Carp	22 and higher	4
Flathead Catfish	All	4
Largemouth Bass	Up to 13	1

Little Calumet River E. coli Total Maximum Daily Load (TMDL) Study

Portions of the Little Calumet River East Branch mainstem have been sampled for many years. Certain sections of the river have failed to comply with the state's water quality standards. Consequently, the state must conduct a TMDL study to address the impairments. The only TMDL study conducted for the LCEB watershed is the "Little Calumet and Portage Burns Waterway TMDL for *E. coli* Bacteria" in 2004 (see Figure 30). The TMDL concluded the dominant source of *E. coli* to be nonpoint source pollution. This TMDL indicates the need for a 90% reduction of *E. coli* bacteria.

IDEM Fixed Station Assessments

Water quality samples have been collected for the IDEM fixed station water quality monitoring program monthly at two sites for the LCEB watershed. These two sites were duplicated for the LCEB baseline study: Site 1 and Site 5. Both sites are on the LCEB mainstem in the Coffee Creek subwatershed. Water quality data has been collected at these sites since 1990.

Site 1 is located on the LCEB mainstem just before the confluence with Burns Waterway on Crisman Road and after the confluence with Salt Creek. Due to its location at the base of the LCEB watershed and receiving flow from the Salt Creek watershed, this sampling site has a

high flow rate that can carry high pollutant loadings with relatively low pollutant concentrations. The mean *E. coli* concentration at Site 1 was 398 CFU/100ml. Nearly a third of the samples collected exceeded the target concentration of 235 CFU/100ml. Mean nitrate concentrations were 1.24 mg/l with 36% of the samples exceeding the target (1.0 mg/l). Eighteen percent of phosphorus samples exceeded the target (0.08 mg/l). The mean phosphorus concentration was 0.04 mg/l. Total suspended solids (TSS) exceeded the state target with only 10% of all samples collected. The mean TSS concentration (19 mg/l) was well below the 30 mg/l target.

Site 5 is located on the LCEB mainstem in Burns Harbor off SR 149. *E. coli* concentrations (mean=747 CFU/100ml) exceeded the target in 60% of samples. Mean nitrate concentrations (1.45 mg/l) were above the target concentration of 1.0 mg/l. Seventy percent of nitrate samples exceeded this target. Mean phosphorus concentrations were 0.04mg/l with 34% of samples exceeding the target. Only 15% of TSS samples exceeded the target. Mean TSS concentrations (15 mg/l) were well below the 30 mg/l target.

1990 Macroinvertebrate Study

The 1990 macroinvertebrate study examined two sites in the LCEB: site 16 (Coffee Creek mainstem) and in the Heron Rookery (Kemper Ditch subwatershed). Site 16 reported an mIBI score of 3.6 (moderately impaired) and a QHEI of 65 (good). The Heron Rookery site was also moderately impaired for macroinvertebrates (mIBI = 2.8) and received an excellent rating for habitat (QHEI = 82).

IDEM 2000 & 2010 Probabilistic/Rotating Basin Monitoring Study

IDEM conducted the 2000 Corvallis study at one LCEB mainstem location near site 9 (off Wagner road). This study assessed general chemistry and metals with 4 sampling dates from June through October in 2000. The fish community (IBI) and habitat (QHEI) were also assessed on one date for this study. State standards were exceeded for many parameters, including turbidity, temperature, nitrate, TSS, phosphorus, and dissolved oxygen. The 2010 Corvallis study was conducted at two LCEB locations: near site 16 and 32. The study was conducted from June through September and examined similar parameters as the 2000 study. State water quality standards were exceeded for temperature, *E. coli*, sediment, and phosphorus. Fish and macroinvertebrate communities were also assessed at site 32.

IDEM 2000 Pesticide Study

IDEM tested for over 143 different pesticides on one LCEB mainstem site near the crossing of US 20 (near site 9). Six pesticides: atrazine, acetoclor, cyanazine, desethylatrazine, metolachlor, and simazine were detected during May and June of that year, corresponding to the seasonality of pesticide use. Pesticides, when present in surface waterways, can contribute to the impairment of biotic communities, because they kill many of the plants or animals. Of the six pesticides detected, only metolachlor is classified as an EPA class C pesticide and carcinogen. Metolachlor had two violations of the benchmark (1 µg/l).

Burns Waterway TMDL 2000 Study

The Burns Waterway TMDL study was conducted at site 1. Samples were collected from July through August for limited water chemistry, *E. coli*, environmental variables, and a few

pesticides. Over 40% of E. coli samples exceeded the target concentration. All temperature readings for this assessment violated the standard for cold water fisheries. Although DO was low (7.0 mg/l), there were no violations for this parameter.

2000 E. coli Study

IDEM's 2000 *E. coli* study was conducted at 4 sites in the LCEB (near sites 1, 5, 13, and 32) and included 5 sampling dates in July and August of 2000. All sites consistently violated the IAC standard of 125 CFU/100ml.

2000 LCEB Study

The 2000 East Branch Little Calumet River IDEM study examined 11 sites in the LCEB: near 1, 5, 9, 10, 23, 32, 33, 44, 45, 46, and 48. These sites were sampled in August 2000 for limited water chemistry, *E. coli*, environmental variables and pesticides. E. coli exceeded targets at most sites and 42% of all samples were above the target concentration. Likewise, most sites had temperature violations and 42% of all samples exceeded the target temperature. There were no dissolved oxygen violations, Nutrients and total suspended solids were not evaluated.

USGS Gage

There are two USGS gages associated with the LCEB watershed. One gage is located at site 1 (gage# 04095090). This gage has recorded discharge since 1994. Since 2011, the gage at site 1 has recorded water temperature, specific conductance, pH, turbidity and dissolved oxygen. A second gage is located at site 9 (gage# 04094000). This gage has recorded stream discharge since 1945.

Summary of Historic Water Quality Sampling Efforts

Several short term water quality studies have been conducted throughout the LCEB watershed in addition to the one long-term study (fixed stations). These studies provide useful historical data and benchmarks for comparing future water quality. These studies also show that water pollution has been degrading the LCEB tributaries for many years and is getting worse over time.

3.2 Current Water Quality Assessment

In 2012, a baseline study of water chemistry and biotic communities in the watershed was performed by IDEM and National Parks Service (NPS) staff on a monthly basis at 48 sampling sites in the watershed (Figure 37). See Appendix 3 for a more detailed description of study sites. This study was conducted monthly for one year between November of 2011 and November of 2012. All study sites were assessed for a variety water chemistry parameters including temperature, dissolved oxygen (DO), DO percent saturation, pH, conductivity, *E. coli* bacteria, nitrogen, phosphorus, sediment, ammonia, chloride, fluoride, sulfate, metals, chemical oxygen demand, and total organic carbon. Flow (discharge) data was also collected at the two tributary outlet sites and on one LCEB main stem site (38, 41, and 43, respectively).

With the assistance of the Great Lakes Innovative Stewardship through Education Network (GLISTEN), Save the Dunes was able to provide additional sampling efforts to the IDEM baseline study. The GLISTEN research assistants, under the direction and supervision of Save the Dunes, performed additional weekly water chemistry sampling at a subset of LCEB sampling locations (sites 9, 12, 20, 22, 32, 34, 38, 43, 44, and 48) during the summer of 2012 (Figure 38). Due to GLISTEN sampling efforts, 11 additional sampling dates occurred between June and August of 2012. Four of these GLISTEN sampling locations (sites 27, 28, 49 and 50) were privately funded by a private donor for inclusion in the LCEB baseline study. These sites were chosen to assess water quality for the tributaries feeding and draining two small lakes in the Kemper Ditch subwatershed: Mar Mac Lake and Rice Lake. Sites 27 and 28 were existing IDEM sampling locations, and sites 49 and 50 were selected to examine the inlet and outlet for Mar Mac Lake. This data is summarized in Section 4.0 Watershed Inventory 3 – Subwatersheds.

The two sampling studies provided a wealth of water quality data, but due a variety of complex issues, basic data analysis was challenging. IDEM, the National Park Service, and Save the Dunes with GLISTEN interns all used different laboratories with differing reporting limits during the sampling campaign. To further complicate things, there was a historic drought during 2012 that made it difficult to detect nonpoint source pollution in many tributaries. When a pollutant is at a level that is too low for the laboratory to detect with their equipment, that parameter is reported back to IDEM or Save the Dunes as a nondetect. The reported value comes back as less than the analytical laboratory's reporting limit. Historically, watershed groups nationwide have substituted zero for these (usually) few and far between non-detect values. This method skews means and other statistics towards lower values than they likely are in reality. This method is typically justified because all data is skewed in the same way, allowing it to be comparable. However, our data (that was collected in 2012) contained a substantial amount of nondetect values. Our dataset also contained differing detection limits for many parameters due to IDEM's use of different analytical laboratories. Consequently, the substitution of zero for nondetect values was statistically inappropriate for the LCEB baseline study. Andrea Bolks, a research fellow at USEPA Region 5, and Jon Harcum, a statistician from TetraTech, assisted Save the Dunes with data analysis. Their statistical expertise allowed us to get a more realistic picture of water quality in the watershed.
See
http://www.bae.ncsu.edu/programs/extension/wqg/319monitoring/tech_notes.htm
for more information on the procedure they used.

LCEB Technical Committee members and Save the Dunes staff conducted windshield surveys in 2012. The LCEB watershed was divided into 12 sections based on the drainage area of major tributary outlets. Each technical committee member chose one or more sections of the watershed to evaluate. Each surveyor identified land use and land cover throughout the watershed. The windshield surveys provided photographs combined with GPS coordinates. However, due to a lack of GPS equipment, not all surveyors were able to collect GPS coordinates. For these circumstances, a detailed description of the location was provided. The information from these surveys was reported out to the LCEB steering committee and additional input on these areas was sought at that time from the rest of the

watershed group. The windshield surveys are summarized in Section 4 of this plan, where the subwatersheds' land use and land cover are discussed.

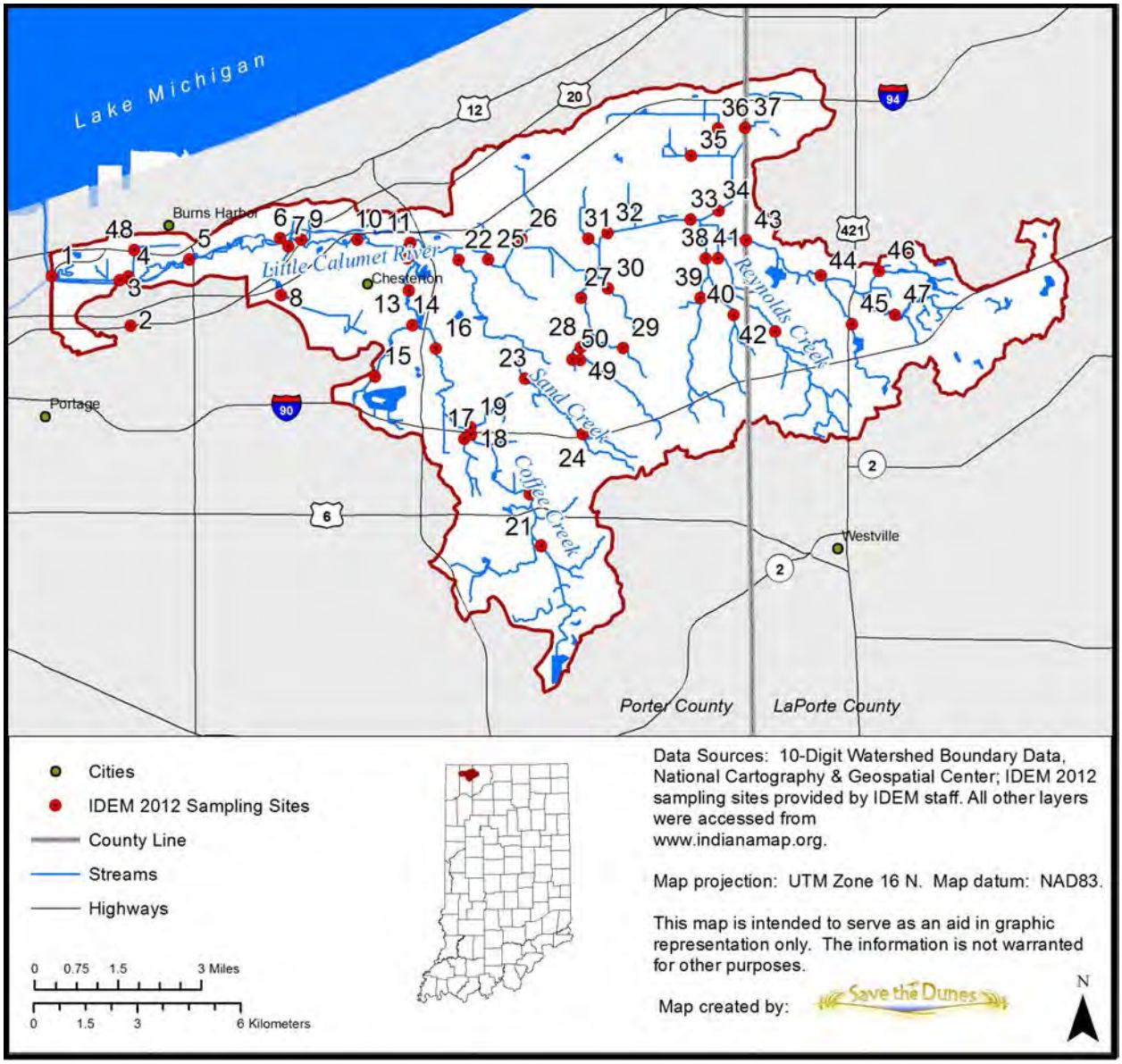

Figure 37. Sampling sites for IDEM's 2012 Baseline study

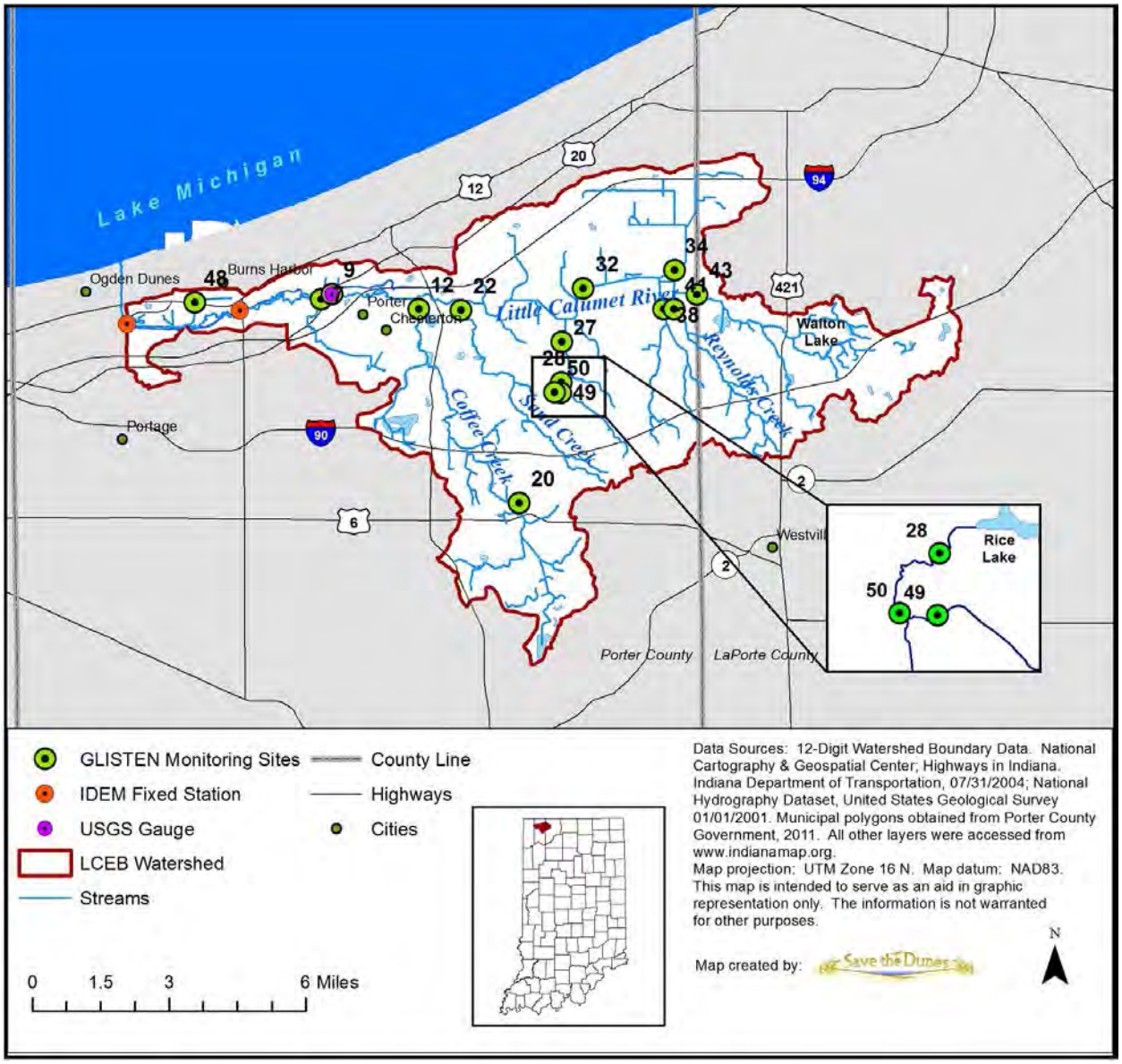

Figure 38. Additional 2012 sampling sites

The following is a detailed description of the parameters analyzed during the stream sampling efforts:

Temperature

Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. For example, water temperature affects the amount of oxygen dissolved in the water column. Water temperature also governs species composition and activity of aquatic biological communities. Since essentially all aquatic organisms are cold-blooded, the temperature of the water regulates their metabolism and ability to survive and reproduce effectively. The IAC (327 IAC 2-1.5-8) sets maximum temperatures to protect aquatic life for Indiana streams in the Great Lakes system according to the time of year. Since the

mainstem of the LCEB and its tributaries downstream of Lake Michigan via Burns Waterway are designated as coldwater salmonid streams, the temperature should not exceed 70 °F (21.1 °C) at any time or 65 °F (18.3 °C) during spawning or imprinting periods. The LCEB watershed group has selected the IAC coldwater standard as the target for stream temperature in the LCEB watershed.

Conductivity

Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, on their total concentration, mobility, and valence (APHA, 1998). During low discharge, conductivity is higher than during high discharge because the water moves more slowly across or through ion containing soils and substrates during base flow. Carbonates and other charged particles (ions) dissolve into the slow-moving water, thereby increasing conductivity measurements. Rather than setting a conductivity standard, the IAC sets a standard for dissolved solids (750 mg/L), which can be converted to a specific conductance range of approximately 1,000 to 1,360 µmhos/cm. The LCEB group chose to not include conductivity in the LCEB targets.

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least three to five mg/L of DO. Coldwater fish such as trout generally require higher concentrations of DO than warmwater fish such as bass or bluegill. The IAC (327 IAC 2-1.5-8) sets the minimum average DO concentrations at five mg/L per calendar day and no less than four mg/L at any time for Indiana streams in the Great Lakes system. Since the LCEB is recognized as a coldwater fishery stream, DO should not fall below six mg/L at any time or below seven mg/L in areas where spawning occurs during the spawning season and in areas used for imprinting during the time salmonids are being imprinted. DO enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with DO. IDEM considers DO values over 12 mg/L to be indicative of an algae or nutrient problem, and sites high DO violations (>12mg/L) for 303(d) assessments if there is a corresponding nutrient, pH, or temperature violation that occurred during the same sampling event for that site. Conversely, DO is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter. The LCEB watershed group has chosen to use the same benchmarks: 6 mg/L as a lower threshold and 12mg/L as an upper threshold. Using a similar method to IDEM's CALM 303(d) assessment methodology, the upper DO violations will only be considered as such if they correspond to another aquatic life use parameter violation: a violation of the target for nutrients, temperature, or pH at the same site during the same sampling event. None of the upper limit violations corresponding to these other parameters occurred during the baseline sampling in 2012.

pH

The pH of water describes the concentration of acidic ions (specifically H+) present in water. Water's pH determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC (327 IAC 2-1.5-8) establishes a range of six to nine pH units for the protection of aquatic life. Concentrations in excess of nine are considered acceptable

when the concentration occurs as daily fluctuations associated with photosynthetic activity. The LCEB group has chosen to use the IAC recommendations for pH as the interim and long term targets for the LCEB watershed. There were no samples showing pH readings outside of the IAC range during the baseline sampling study that was conducted in 2012.

Nutrients

Nutrient concentrations can estimate the amount of algae growth and/or rooted plant (macrophyte) growth that is possible in a stream. Algae and other plants are a natural and necessary part of aquatic ecosystems. Both will always occur in a healthy stream. Algal and rooted plant growth can, however, reach nuisance levels and interfere with the aesthetic and recreational uses of a stream. Nutrients themselves, as well as the primary producers (algae and plants) they feed, can also affect the composition of secondary producer communities such as macroinvertebrates and fish. Changes in secondary producer communities can, in turn, impact the way chemical constituents in the water are processed. Common sources of nutrients are fertilizers from lawns and agricultural fields, leaking septic systems, and manure or other animal wastes.

Phosphorus and nitrogen have several chemical forms in water. Two common forms of phosphorus are soluble reactive phosphorus (SRP) and total phosphorus (TP). SRP is a measure of orthophosphate and is a dissolved form of phosphorus. It is a form that is directly usable by plants. Algae cannot directly digest and use particulate phosphorus. Total phosphorus is a measure of both dissolved and particulate forms of phosphorus. IDEM and Save the Dunes both sampled total phosphorus during the baseline study that occurred in 2012. The LCEB watershed group has chosen 0.08mg/L, the Ohio EPA recommendation, as the target for streams in the watershed.

The most commonly measured nitrogen forms are nitrate-nitrogen (NO_3) and ammonia-nitrogen (NH_3). Nitrate is a common form of nitrogen that can be found in a moving stream or anywhere that oxygen is readily available. Because oxygen is typically available in stream systems, nitrate-nitrogen is the dominant dissolved form of nitrogen in stream systems. In contrast, ammonia-nitrogen is present where oxygen is lacking. Ammonia is a byproduct of decomposition generated by bacteria as they decompose organic material. It can be extremely harmful to fish and other aquatic organisms. The target chosen for nitrate is 1.0 mg/L **(**OEPA, 1999**)**. The IAC does have a drinking water standard for nitrate, 10 mg/L, but the LCEB technical committee decided this was too high to protect aquatic life. The IAC has two different recommendations for ammonia concentrations in Indiana streams and rivers. One recommendation is for the Great Lakes region and the other pertains to the rest of the state. Both IAC recommendations for ammonia are based on pH and temperature, yielding a range of values due to current conditions. The IAC's Great Lakes region ammonia standard ranges from 0.8254-28.47 mg/L, while the standard for the rest of the state is 0.0075-0.2137 mg/L. Standards for the Great Lakes region do apply to the LCEB watershed however, the technical committee decided to use the more stringent IAC ammonia standard (0.0075-0.2137 mg/L).

Total Suspended Solids (TSS)

A TSS measurement quantifies all particles suspended and dissolved in water. Closely related to turbidity, which is a measure of the cloudiness of water caused by particles that can be seen with the human eye, TSS quantifies sediment particles and other solid compounds typically found in water, including those too small to see without a microscope. In general, the concentration of suspended solids is greater in streams during high flow events due to increased overland flow and resuspension of previously settled or attached material. The increased overland flow can erode hillsides and streambanks carrying more soil and other particulates to the stream. The sediment in water originates from many sources, but a large portion of sediment entering streams can come from active construction sites or other disturbed areas such as unvegetated stream banks and poorly managed farm fields.

Suspended solids impact streams in a variety of ways. When suspended in the water column, solids can clog the gills of fish and some macroinvertebrates. As the sediment settles to the stream bottom, it covers spawning and resting habitat for aquatic fauna, reducing the animals' reproductive success. Suspended sediments also impair the aesthetic and recreational value of a waterbody. Pollutants, such as phosphorus, attach to sediment and also degrade water quality. In general, TSS concentrations greater than 80 mg/L have been found to be deleterious to aquatic life, although TSS concentrations between 25 and 80 mg/L have been known to reduce fish concentrations (Waters, 1995). IDEM does not have a water quality standard for TSS, however it does have a draft target for TMDLs of 30 mg/L, which is what the LCEB watershed group has chosen for the TSS target.

Escherichia coli (E. coli) Bacteria

E. coli is one member of a group of bacteria that comprise the fecal coliform bacteria and is used as an indicator organism to identify the potential for the presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments, and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum concentration of *E. coli* at 235 colony forming units (CFU)/ 100 ml in any one sample within a 30-day period. For data sets consisting of five equally spaced samples over a 30-day period, the geometric mean must not exceed 125 CFU/ 100mL and not more than one sample shall exceed 576 CFU/ 100 ml. For data sets consisting of 10 or more grab samples where no five of which are equally spaced over a 30-day period not more than 10% of measurements shall exceed 576 CFU/ 100mL and not more than one sample shall exceed 2,400 CFU/ml. The LCEB has chosen to use 235 CFU/100 ml as the target for LCEB streams. *E. coli* was analyzed using the Colilert® method by both IDEM and Save the Dunes, which yields results in terms of most probable number (MPN) per 100 ml. These units are virtually identical to CFU, and so the targets are applicable to *E. coli* analyzed with this method.

Metals

While the presence of small amounts of some metals in drinking water can be beneficial to human health, their presence in surface waters can be toxic to aquatic life. When metals are found in surface waterways in a dissolved form, they can be taken up through the gills of aquatic organisms and cause death. While total metal concentrations were analyzed the most before 1993, and are currently analyzed for surface waterways in Indiana as of the writing of this plan, they can show a value that is higher than the actual amount available to biological living creatures. Heavy metals, such as Copper (Cu), Iron (Fe), Cadmium (Cd), Zinc (Zn), Mercury (Hg), and Lead (Pb) are considered the most harmful to aquatic organisms (USEPA 1996) The toxicity of metals in surface waterways can be influenced by several other parameters, including temperature, pH, hardness (usually as Calcium carbonate [$CaCO_3$] concentration), alkalinity, suspended solids concentration, redox potential and dissolved organic carbon. Metals can also bind to other inorganic compounds, which can result in a lower toxicity. Water quality criteria for metals in the IAC are in terms of dissolved metals. Many rivers in the LCEB watershed are fed by fens, a type of natural spring, which can result in naturally high concentrations of metals and minerals, such as iron, magnesium, and calcium, to surface waterways.

The 2012 baseline study performed by IDEM utilized analysis methods for a wide variety of total recoverable metals, including antimony, arsenic, beryllium, cadmium, calcium, copper, chromium, lead, magnesium, nickel, selenium, silver, thallium and zinc. These data could not be compared to applicable numeric aquatic life standards for dissolved metals without other parameters. For example, using EPA's Biotic Ligand Model to determine the aquatic life criteria for copper, one would need concentrations for ten other parameters, including dissolved organic carbon, which was not sampled by IDEM in 2012. The LCEB watershed group set no targets for metals.

Pesticides

The term pesticide covers a broad category that includes herbicides, insecticides, fungicides, rodenticides, and any other poisons meant to kill unwanted plants, insects, fungi, or rodents that are considered harmful to cultivated crops or animals. The presence and concentration of pesticides in surface waterways tends to correspond to the agricultural and recreational season, when farmers, homeowners, or commercial companies apply them to the land. Over 1 billion pounds of pesticides are applied in the United States every year (Gillom et al. 2006). There are numerous varieties and metabolites of currently used pesticides, but currently Maximum Contaminant Loads (MCLs) for surface waters only exist for 9 of them. The LCEB watershed group selected no targets for pesticides, because no current data exists.

Benthic Macroinvertebrates

Benthic macroinvertebrates are aquatic invertebrates that live in the bottom portions of our waters. They make good indicators of watershed health because they live in the water for all or most of their lives, are easy to collect, differ in their tolerance to amount and types of pollution, are easy to identify in a laboratory, often live for more than one year, have limited mobility, and are integrators of environmental condition. The benthic macroinvertebrate community in the LCEB watershed was evaluated using IDEM's

macroinvertebrate Index of Biotic Integrity (mIBI). The mIBI is a multi-metric index that combines several aspects of the benthic community composition. As such, it is designed to provide a complete assessment of a creek's biological integrity. Karr and Dudley (1981) define biological integrity as *the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to the best natural habitats within a region.* The mIBI is calculated by averaging the classification scores for associated metrics, based on the multi-habitat macroinvertebrate collection procedure (mHAB) methodology utilized by IDEM for the CALM assessment. Using this method, mIBI scores that are greater than 36 are said to be fully supportive of benthic macroinvertebrate communities. If an mIBI score shows that a river is not supporting macroinvertebrate communities, a qualitative habitat evaluation index (QHEI) is calculated for the stream reach to help determine if the nonsupporting status is caused by poor water quality or poor habitat.

Although the IAC does not include mIBI scores as numeric criteria for establishing whether streams meet their aquatic life use designation, IDEM will be using mIBI scores as well as other information (temperature, dissolved oxygen, nutrients, sediment, and pH) to make this determination. Under state law, all waters of the state, except for those noted as Limited Use in the IAC, must be capable of supporting recreational and aquatic life uses. In the 2010 303(d) consolidated assessment and listing methodology (CALM), IDEM suggests that those waterbodies with mIBI scores less than 36 when using the multi-habitat approach are considered non-supporting for aquatic life use. Under federal law, waters that do not meet their designated uses must be placed on the 303(d) list and remediation/restoration plans (total maximum daily load (TMDL) plans) must be developed for these waters in order to take action to reduce pollution levels. The LCEB Watershed Group selected 36 mIBI score as the target for streams in this watershed.

Fish Communities

Fish communities are assessed using the multi-metric index of biotic integrity (IBI). The 12 metrics associated with this index include the number of fish and species, as well as the species' varied tolerances to pollution, among other metrics. Site-specific results will be discussed in further detail in Section 4.

In the event that an IBI score shows a river is not supportive of fish communities, a QHEI was calculated by IDEM to assess the adjacent habitat, to see if the fish communities are struggling due to water quality or habitat degradation. If the QHEI score shows that the habitat should support fish populations, water pollution is the most likely stressor.

Although the IAC does not include IBI scores as numeric criteria for establishing whether streams meet their aquatic life use designation, IDEM may be using IBI scores to make this determination. (Under state law, all waters of the state, except for those noted as Limited Use in the IAC, must be capable of supporting recreational and aquatic life uses.) In the 2010 303(d) consolidated assessment and listing methodology (CALM), IDEM states that waterbodies with IBI scores less than 36 are considered non-supporting for aquatic life use. Under federal law, waters that do not meet their designated uses must be placed on the 303(d) list and remediation/restoration plans (TMDL plans) must be developed for these

waters. The LCEB Watershed Group selected 36 IBI score as the target for streams in this watershed.

Habitat

The physical habitat at the sampling sites where streams were found to have scores that are non-supporting for the mIBI or IBI indices was evaluated using the QHEI. The Ohio EPA developed the QHEI for streams and rivers in Ohio (Rankin 1989, 1995). The QHEI is a physical habitat index designed to provide an empirical, quantified evaluation of the general lotic (flowing water) habitat (OEPA, 1989). While the Ohio EPA originally developed the QHEI to evaluate fish habitat in streams, IDEM and other agencies routinely utilize the QHEI as a measure of general "habitat" health. The QHEI is composed of six metrics including substrate composition, in-stream cover, channel morphology, riparian zone and bank erosion, pool/glide and riffle-run quality, and map gradient. Observations of stream conditions along a 200-foot (61 meter) reach are recorded on the QHEI datasheet. Each metric is then scored individually then summed to provide the total QHEI score. The habitat assessed at each reach may not be representative of habitat present throughout the stream system or subwatershed. Rather the QHEI score represents the habitat present within that 200-foot (61 meter) reach of the sampling site where non-supporting indices were calculated.

Substrate type and quality are important factors of habitat quality and the QHEI score is partially based on these characteristics. Sites that have greater substrate diversity receive higher scores as they can provide greater habitat diversity for benthic organisms. The quality of substrate refers to the embeddedness of the benthic zone. Because the rocks (gravel, cobble, and boulder) that comprise a stream's substrate do not fit together perfectly like pieces in a jigsaw puzzle, small pores and crevices exist between the rocks in the stream's substrate. Many stream organisms can colonize these pores and crevices, or microhabitats. In streams that carry high silt loads, the pores and crevices between rock substrate become clogged over time. This clogging, or embedding, of the stream's substrate eliminates habitat for the stream's biota. Thus, sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

In-stream cover, another metric of the QHEI, refers to the type(s) and quantity of habitat provided within the stream itself. Examples of in-stream cover include woody logs and debris, aquatic and overhanging vegetation, and root wads extending from the stream banks. The channel morphology metric evaluates the stream's physical development with respect to habitat diversity. Pool and riffle development within the stream reach, the channel sinuosity, and other factors that represent the stability and direct modification of the site comprise this metric score.

A stream's buffer, which includes the riparian zone and floodplain zone, is a vital functional component of riverine ecosystems. It is instrumental in the detention, removal, and assimilation of nutrients. Riparian zones govern the quality of goods and services provided by riverine ecosystems (Ohio EPA, 1999). Riparian zone (the area immediately adjacent to the stream), floodplain zone (the area beyond the riparian zone that may influence the stream though runoff), and bank erosion were examined at each site to evaluate the quality

of the buffer zone of the stream, the land use within the floodplain that affects inputs to the waterway, and the extent of erosion in the stream, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian zone consists only of forest, shrub, swamp, or woody vegetation. Typically, weedy, herbaceous vegetation has higher runoff potential than woody components and does not represent an acceptable riparian zone type for the QHEI (OEPA, 1989). Streams with grass or other herbaceous vegetation growing in the riparian zone receive low QHEI scores for this metric.

Metric 5 of the QHEI evaluates the quality of pool/glide and riffle/run habitats in the stream. These zones in a stream, when present, provide diverse habitat and, in turn, can increase habitat quality. The depth of pools within a reach and the stability of riffle substrate are some factors that affect the QHEI score in this metric.

The final QHEI metric evaluates the topographic gradient in a stream reach. This is calculated using topographic data. The score for this metric is based on the premise that both very low and very high gradient streams will have negative effects on habitat quality. Moderate gradient streams receive the highest score, 10, for this metric. The gradient ranges for scoring take into account the varying influence of gradient with stream size.

The QHEI evaluates the characteristics of a stream segment as opposed to the characteristics of the entire stream. Therefore, it must be noted that the segment is in some cases only representative of a small fraction of the streams/headwaters within the sampling site's subwatershed. QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are generally conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (OEPA, 1999). IDEM indicates that higher QHEI scores represents more diverse habitat for colonization by macroinvertebrates. Scores below 51 suggest that poor habitat may be limiting biota within the association stream. The LCEB Watershed Group selected 51 QHEI score as the target for streams in this watershed.

3.3 Water Quality Targets

Water quality standards, or targets, were selected for water chemistry parameters in the baseline study. These water quality targets are based on applicable Indiana Administrative Code and other standards accepted by the Indiana Department of Environmental Management. IDEM also collected additional water chemistry parameters, such as metals and pesticides. Unfortunately, the samples collected by IDEM for this study were analyzed for total metals, while the IAC only has targets for dissolved metals.

Table 13. Water quality targets

Parameter	Target	Source
Benthic Macroinvertebrate Community	mIBI ≥ 36 indicates full support (scores range from 12-60)	Indiana Administrative Code [327 IAC 2-1-3(2), 327 IAC 2-1-9(49)]
Dissolved Oxygen (DO)	Minimum: 6 mg/L Minimum: 7 mg/L in areas where spawning and imprinting occurs Maximum: 12 mg/L during the growing season	Indiana Administrative Code (327 IAC 2-1.5-8)
E. coli	Maximum: 235 CFU/100 mL in a single sample Maximum: geometric mean of 125 CFU/100 mL from 5 equally spaced samples over a 30-day period	Indiana Administrative Code (327 IAC 2-1.5-8)
Fish Community (IBI)	IBI ≥ 36 indicates full support (scores range from 0-60)	Indiana Administrative Code [327 IAC 2-1-3(2), 327 IAC 2-1-9(49)]
Nitrate-Nitrogen (NO_3)	Maximum: 1 mg/L	Ohio EPA recommended criteria for Warm Water Habitat (WWH) headwater streams
pH	No pH values below six (6) or above nine (9)	Indiana Administrative Code (327 IAC 2-1.5-8)
Habitat (QHEI)	QHEI > 51 indicates fair quality (scores range from 0-100)	IDEM CALM: The Qualitative Habitat Evaluation Index (QHEI) is not used to determine aquatic life use support. The QHEI is an index designed to evaluate the lotic habitat quality important to aquatic communities and is used in conjunction with mIBI or IBI data, or both to evaluate the role that habitat plays in waterbodies where impaired biotic communities have been identified
Temperature	Maximum: 70°F or 21.1°C Maximum: 65°F or 18.3°C during spawning or imprinting periods	Indiana Administrative Code (327 IAC 2-1.5-8)
Total Ammonia (NH_4)	Range between 0.0 and 0.21 mg/L depending upon temperature and pH	Indiana Administrative Code (327 IAC 2-1-6)
Total Phosphorus (TP)	Maximum: 0.08 mg/L	Ohio EPA recommended criteria for Warm Water Habitat (WWH) headwater streams
Total Suspended Solids	Maximum: 30 mg/L	IDEM draft TMDL target from NPDES rule for lake dischargers in 327 IAC 5-10-4 re: monthly average for winter limits for small sanitary treatment plants