Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

MONITORING AND RESEARCH DEPARTMENT

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AMBIENT WATER QUALITY MONITORING IN THE CALUMET RIVER SYSTEM: AN EXAMINATION OF BIOLOGICAL, HABITAT, SEDIMENT, AND WATER QUALITY BETWEEN 2001 AND 2012

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LIST OF ABBREVIATIONS

Abbreviation/Acronym	Definition
130^{th} Street	130^{th} Street on the Calumet River
170^{th} Street	170^{th} Street on Thorn Creek
ACOE	United States Army Corps of Engineers
ANOVA	analysis of variance
Ashland LCR-S	Ashland Avenue on the Little Calumet River South
AVS	acid volatile sulfides
AWQM	Ambient Water Quality Monitoring
AWQMP	Ambient Water Quality Monitoring Program
Burnham GCR	Burnham Avenue on the Grand Calumet River
Burnham IC	Burnham Avenue on Indian Creek
CAWS	Chicago Area Waterway System
CAWSHI	Chicago Area Waterway System Habitat Index
CDOM	continuous dissolved oxygen monitoring
Cicero Avenue	Cicero Avenue on the Calumet-Sag Channel
COC	chemicals of concern
CPUE	catch per unit effort
CRS	Calumet River System
CSC	Calumet-Sag Channel
CSOs	combined sewer overflows
District	Metropolitan Water Reclamation District of Greater Chicago
DO	dissolved oxygen
EPT	Ephemeroptera, Plecoptera, Trichoptera
Ewing Avenue	Ewing Avenue on the Calumet River
GCR	Grand Calumet River
GPP	generator-powered pulsator
Halsted Street	Halsted Street on the Little Calumet River North
HBI	Hilsenhoff Biotic Index
HD	Hester Dendy
IBI	index of biotic integrity
IEPA	Illinois Environmental Protection Agency
Indiana Avenue	Indiana Avenue on the Little Calumet River North
Joe Orr	Joe Orr Road on Thorn Creek
LCR-N	Little Calumet River North
LCR-S	Little Calumet River South
NH_3-N	ammonia nitrogen
$NO_2 + NO_3$	nitrite plus nitrate nitrogen
NSC	North Shore Channel
OPPs	organic priority pollutants
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls

LIST OF ABBREVIATIONS (Continued)

Abbreviation/Acronym	Definition
PEC	probable effect concentration
PP	Petite Ponar grab sampler
QHEI	qualitative habitat evaluation index
Route 83	Route 83 on the Calumet-Sag Channel
SEM	simultaneously extracted metals
SEPA	Sidestream Elevated Pool Aeration
SQGs	sediment quality guidelines
TALU	tiered aquatic life use
TAN	total ammonia nitrogen
TARP	Tunnel and Reservoir Plan
TCN	total cyanide
TEC	threshold effect concentration
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TP	total phosphorus
TS	total solids
TSS	total suspended solids
TVS	total volatile solids
UAA	use attainability analysis
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Wentworth Avenue	Wentworth Avenue on the Little Calumet River South
WRP	water reclamation plant

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DISCLAIMER

Mention of proprietary equipment and chemicals in this report does not constitute endorsement by the Metropolitan Water Reclamation District of Greater Chicago.

SUMMARY AND CONCLUSIONS

Description of the Program

The Metropolitan Water Reclamation District of Greater Chicago (District) service area waterways consist of man-made canals and natural streams which have been altered to varying degrees. Some natural waterways have been deepened, straightened, and/or widened. During the monitoring period of 2001 to 2012, the waterways served the Chicago area by draining urban stormwater runoff and treated municipal wastewater effluent and by allowing commercial navigation in the deep draft portions. The Calumet River System (CRS) includes the Calumet-Sag Channel (CSC), the Calumet River, the Little Calumet River (referred to as the LCR-N), the wadeable portion of the LCR (referred to as the LCR-S), Thorn Creek, the Grand Calumet River (GCR), and Indian Creek. Data collected on the biological, habitat, and sediment quality from 13 sampling stations in the CRS between 2001 and 2012 were evaluated.

Significant Findings

Overall, habitat was a major limiting factor for aquatic life in the CRS because it is predominantly manmade or man-altered. Habitat quality was poor in most of the waterways in the CRS and did not change, or changed very little, between 2001 and 2012. Habitat improvements like removal of vertical wall banks and installation of vegetated revetments, chamber revetments, sunken structures, floating vegetation, artificial seaweed and linear shallows could improve the quality of fish habitat in the deep draft waterways in the CRS, if the original intended functionality of drainage and commercial navigation could still be maintained (LimnoTech, 2010). Wadeable waterways in the CRS could benefit greatly from substrate improvements and development of riffle/pool complexes.

Statistical and trend analysis of chemical data from locations on the CRS showed that there was little change in water quality between 2001 and 2012, even though there were improvements in treatment of wastewater through the completion of the Calumet Tunnel and Reservoir Plan (TARP) Tunnel System (2006) and activation of the Thornton transitional reservoir (2003). Analysis of variance (ANOVA) and the Mann-Kendall method were utilized to analyze Ambient Water Quality Monitoring (AWQM) and Continuous Dissolved Oxygen Monitoring (CDOM) data that were collected at the same locations as the biological monitoring in the CRS. The analysis showed that there was either no significant difference among yearly data or no trend identified for total suspended solids (TSS) between 2001–2012 at any AWQM stations except 130th Street and Indiana Avenue on the LCR-N (Indiana Avenue), where the Mann-Kendall analysis demonstrated a negative TSS trend. Total ammonia nitrogen (TAN) concentrations were decreasing over the study period at Ewing Avenue on the Calumet River (Ewing Avenue) and 170th Street on Thorn Creek (170th Street), but increasing at Burnham Avenue on the GCR (Burnham GCR) and Cicero Avenue on the CSC. There were otherwise no significant trends identified for TAN at any CRS locations. Of all the CDOM stations, only 104th Street on the CSC demonstrated a decreasing dissolved oxygen (DO) trend between 2001–2010. The rest of the stations exhibited either no significant difference among years or no DO trend.

Sediment chemistry data did not yield any clearly identified spatial or temporal patterns in most of the CRS, because concentrations were variable within each station and among sampling locations. Sediment was only sampled two times (2003 and 2007) between 2001 and 2012, which is not ideal for statistical or trend analyses. However, some of the chemical parameters showed higher concentrations in some of the downstream segments of waterways. Consensus-based sediment quality guidelines (SQGs) were used to assess sediment contamination of various chemicals of concern (COC). The COC included various metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and organochlorine pesticides. Cicero Avenue, Route 83 on the CSC (Route 83), and Burnham GCR had the highest incidence of concentrations of COC above the probable effect concentration (PEC). Not surprisingly, these same stations also had the highest percentage of samples that displayed toxicity during ten-day *Chironomus tentans* tests.

Overall, the benthic community in the CRS largely consisted of tolerant taxa. Six of the seven waterways in the CRS were dominated by Annelida (aquatic worms). Variability of taxa richness was most evident at stations that were sampled annually (Halsted Street on the LCR-N [Halsted Street], Cicero Avenue, and 130th Street on the Calumet River (130th Street), where a large difference was seen at times between the maximum and minimum number of taxa collected within a location. Mean Hilsenhoff Biotic Index (HBI) scores were calculated for each station and waterway that was sampled in the CRS. The HBI score estimates the overall tolerance of the benthic community in the sample area, weighted by the relative abundance of each taxonomic group. Organisms were assigned a tolerance number from 0 to 10 depending on the taxonomic groups' known sensitivity to organic pollutants, 0 being the most sensitive and 10 being the most tolerant. Variation of mean HBI scores was most evident in Hester Dendy (HD) samples at the stations that were sampled annually, but scores were mostly categorized as Fairly Poor or Poor.

Fish species richness and abundance varied spatially and temporally at stations throughout the CRS, due to the inherent variability of fish sampling and the proximity to Lake Michigan. Gizzard shad (*Dorosoma cepedianum*) was the most abundant fish species in the CRS, and the relative abundance of gizzard shad increased as the distance from Lake Michigan increased, at stations where boat electrofishing methods were used. Index of Biotic Integrity (IBI) scores were calculated for each sampling event at each sampling station in the CRS between 2001 and 2012, using Karr's 1986 IBI. Overall, most of the scores were in the Fair category because of low amounts of darter, sucker, and intolerant species, and high proportions of omnivores, but almost all of the individual fish metrics were variable at most of the locations that were sampled. Variability in metrics caused IBI scores to be variable from year to year and no significant temporal improvements or decreases in IBI scores were evident.

Future Monitoring

Water quality did not change measurably between 2001 and 2012, but water quality in the District service area waterways was significantly improved in the prior 30 years due to various improvements in wastewater treatment and the TARP. The District is currently working on a number of major projects to further enhance water quality and positively impact the Chicago area waterways. Improvements resulting from such investments can be documented through long-term biomonitoring and water sampling. Standardized annual fish sampling can statistically show changes in species richness, abundance, and integrity, while data generated via quadrennial basin based fish sampling provides information about presence and absence of fish species with little statistical significance. Biological integrity, as represented by fish and invertebrate monitoring, shows progress towards the primary goal of the Clean Water Act: to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Only fish integrate all of the desired ecosystem evaluation components: water quality, habitat, many trophic levels, sediment quality, and food source (macroinvertebrates, algae). Biological improvements in fish species and health resonate with the public, and represent more accessible and understandable metrics than a compilation of water quality parameters. Biomonitoring in the Chicago area waterways will continue to be a powerful tool that can integrate and substantiate improvements in water quality and habitat over time.

INTRODUCTION

The District's service area waterways consist of man-made canals as well as natural streams which have been altered to varying degrees. Some natural waterways have been modified by being deepened, straightened, and/or widened to such an extent that reversion to their natural state would be impossible. The waterways serve the Chicago area by draining urban stormwater runoff and treated municipal wastewater effluent and allowing commercial navigation in the deep draft portions.

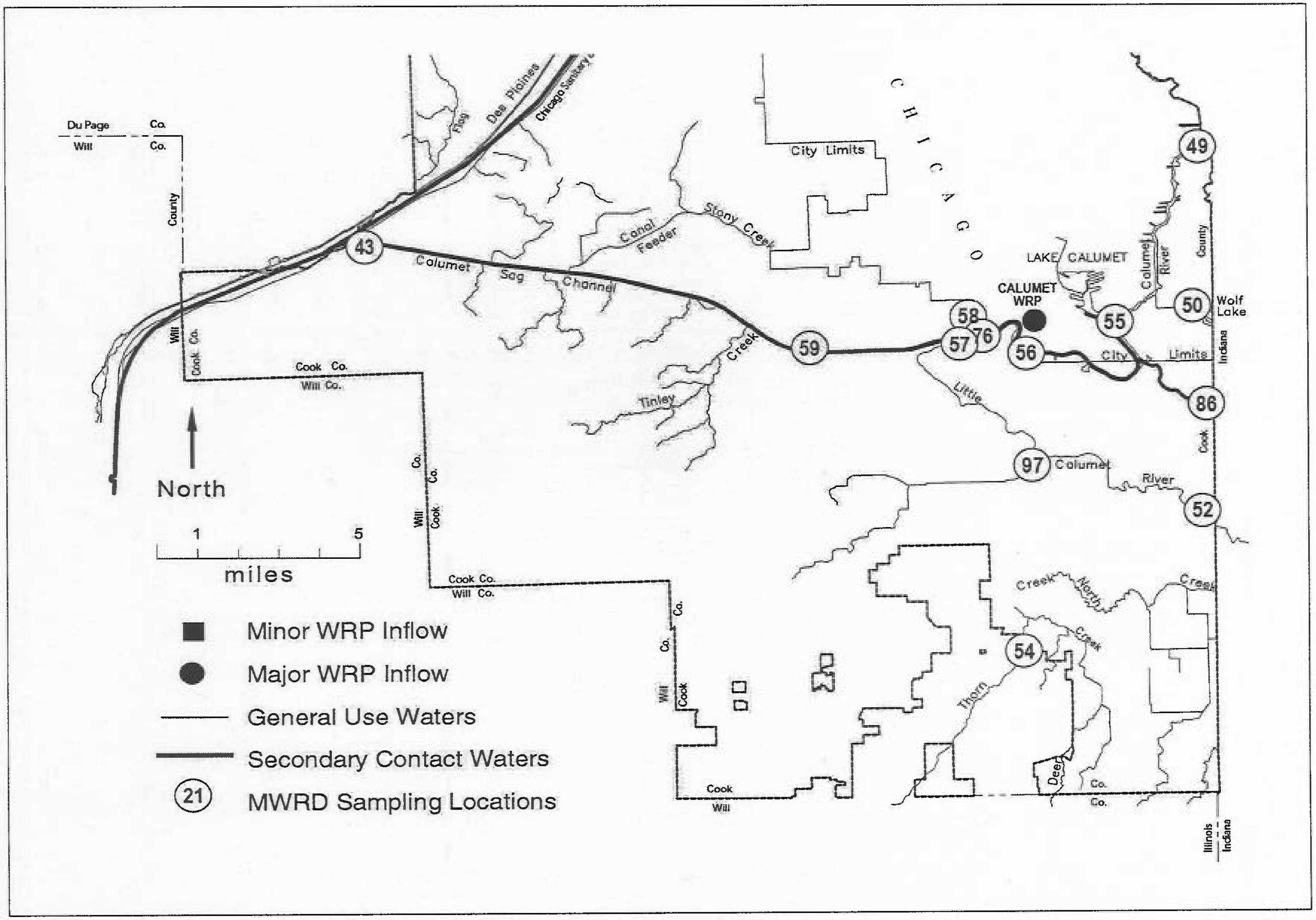
Biological assessments were performed in the District's service area at 59 Ambient Water Quality Monitoring Program (AWQMP) stations between 2001 and 2012. More information about water sampling and analyses performed for the District's AWQMP can be accessed on our website (mwrd.org). Biological monitoring operated on a four-year cycle, with the primary focus on a different river system in the service area each year. The four river systems of interest were the northern portion of the Chicago River System, the southern portion of the Chicago River System, the CRS, and the Des Plaines River System. Fifteen of the 59 stations located across all of the waterways were monitored annually based on their proximity to District water reclamation plants (WRPs) or municipal boundaries. This report focuses on the biological, habitat, and sediment quality at 13 sampling stations in the CRS between 2001 and 2012. Three sampling stations were located on the CSC, and two sampling stations each were located on the Calumet River, the deep draft portion of the LCR, or LCR-N, the wadeable portion of the LCR, or LCR-S, and Thorn Creek. Only one sampling station each was located on the GCR and Indian Creek. A map of the thirteen biological sampling stations in the CRS is shown in <u>Figure 1</u>.

Biological monitoring represents an important tool for assessing the impacts of various stressors on an aquatic environment and evaluating long term changes to a system, integrating water quality and habitat. Fish monitoring, in particular, can integrate multiple ecosystem evaluation components like water and sediment quality, habitat, flow conditions, trophic level interactions, and food source. Changes in biological integrity, as represented by fish and invertebrate monitoring, can demonstrate progress towards Clean Water Act goals, as efforts are made to improve water quality and habitat in a watershed.

The most recent Illinois 303(d) List (Illinois Environmental Protection Agency [IEPA], 2014) reported that the CSC, LCR-N, and the GCR did not meet Indigenous Aquatic Life Use goals, and the LCR-S and Thorn Creek failed to meet General Use Aquatic Life Use goals. Common causes of Indigenous Aquatic Life Use impairments included DO, total dissolved solids, iron, and other heavy metals, particularly in the GCR where fourteen Aquatic Life Use impairments were listed. Common sources of impairment included combined sewer overflows (CSOs), urban runoff/storm sewers, channelization, contaminated sediment, sediment resuspension, flow modification, and upstream impoundments. Thorn Creek and the LCR-S were listed as impaired for various organic contaminants, DO, and chloride, with sources including habitat modification, CSOs, urban runoff/storm sewers, municipal point sources, loss of riparian habitat, channelization, contaminated sediment, streambank modification/destabilization, and upstream impoundments.

Clearly, many of the potential sources of Aquatic Life Use impairment in the CRS are, to some extent, irreversible or would require major physical reconstruction projects to alleviate. In

FIGURE 1: CALUMET RIVER SYSTEM AMBIENT WATER QUALITY MONITORING PROGRAM SAMPLING STATIONS



such a case, a Use Attainability Analysis (UAA) can be undertaken to assign appropriate potential aquatic life uses and water quality standards, taking into account "human caused conditions or sources of pollution," or "hydrologic modifications" that preclude the attainment of Clean Water Act goals. The IEPA used biological, habitat, and water chemistry data collected by the District during 2001 to 2006 to perform a UAA on the Chicago Area Waterway System (CAWS). The CAWS UAA upgraded the Indigenous Aquatic Life Use to CAWS Aquatic Life Use A in the LCR-N, CSC, and GCR. The new limited use is still meant to reflect "unique physical conditions, flow patterns, and operational controls necessary to maintain navigational use, flood control, and drainage functions of the waterway system." (35 IAC, Section 303.235). New standards to protect CAWS Aquatic Life Use A Waters became effective on July 1, 2015.

Over the past several decades, the District has enhanced water quality in the CRS through improved treatment at the Calumet WRP, completion of TARP tunnels, and construction and operation of Sidestream Elevated Pool Aeration (SEPA) Stations. During the span of AWQMP, the Thornton transitional reservoir was activated (2003) and in 2006 the Calumet TARP Tunnel System was also completed. In more recent years, the District completed the Thornton Composite Reservoir portion of TARP (2015), and started disinfecting effluent at the Calumet WRP (2016). Over the next decade, reducing phosphorus discharge and increasing amounts of green infrastructure are likely to further improve CRS water quality. However, the CAWS UAA has indicated that the lack of adequate physical habitat presents the most significant stressor for aquatic life in these largely artificial urban waterways (CDM, 2007; LimnoTech, 2010). These studies suggest that future investments in habitat improvement and restoration of ecological function will be necessary to further increase biological integrity in the CRS.

MATERIALS AND METHODS

Fish collection, habitat assessment, and benthic invertebrate collection were done annually at the CRS at 130th Street, Halsted Street, and Cicero Avenue Stations. The remaining 10 stations in the CRS were sampled for the same parameters during 2003, 2007, and 2011. Sediment analyses for toxicity and chemical components were done only in 2003 and 2007; no sediment was collected in 2011. The sampling dates for fish collection, habitat assessments, benthic invertebrates, and sediment collection for CRS AWQMP stations between 2001 and 2012 are shown in Table 1.

Habitat

Two waterway classifications exist in the Chicago region: wadeable and deep draft (navigable). Each of these requires a separate method of analysis for habitat. Wadeable streams were assessed using the Qualitative Habitat Evaluation Index (QHEI). Deep draft waterways were assessed using a habitat index developed by LimnoTech specifically for the CAWS (LimnoTech, 2010). The QHEI assessment of the entire 40-meter reach sampled for fish in wadeable waterways was performed visually by a staff biologist. Categories assessed are as follows: substrate (type, origin, and quality), instream cover (type and amount), channel morphology (sinuosity, development, channelization, and stability), bank erosion and riparian zone (erosion amount, riparian width, and flood plain quality), pool/glide and riffle/run quality (maximum depth, channel width, and current velocity), and gradient. LimnoTech assessed riparian vegetation, bank condition and angle, overhanging vegetation, bank pocket areas, and off channel bays in the field. LimnoTech also supplemented its data with physical habitat data collected by the District, the Army Corps of Engineers (ACOE), Illinois State Geological Survey, the United States Geological Survey (USGS), and the Northeastern Illinois Planning Commission.

Calculating Qualitative Habitat Evaluation Index Scores. The QHEI was developed by the Ohio Environmental Protection Agency to determine the suitability of a stretch of waterway to fish and macroinvertebrates based on physical habitat characteristics (Rankin, 1989). The index was developed to assess wadeable streams, not deep draft channels such as those prevalent in the Chicago area. Appendix A shows the QHEI Field Assessment Form. Habitat scores were calculated using the Ohio QHEI procedures for assessing the quality of substrates, instream cover, channel morphology, riparian zone/erosion, pool and riffle/run development, and stream gradient. Sites were then classified as Excellent, Good, Fair, Poor, or Very Poor based on their ability to support aquatic life in reference to habitat (Rankin, 2004). The classification ranges were as follows:

≥75	Excellent
60–74	Good
46–59	Fair
30–45	Poor
<30	Very Poor

TABLE 1: SAMPLING DATES FOR AMBIENT WATER QUALITY MONITORING PROGRAM STATIONS IN THE CALUMET RIVER SYSTEM DURING 2001 THROUGH 2012

Station No.	Sampling Station	Waterway	Fish	Habitat Assessment	Benthic Invertebrates	Sediment Quality
49	Ewing Avenue	Calumet River	08/01/2003	08/01/2003	08/01/2003	08/01/2003
			07/26/2007	07/26/2007	07/26/2007	07/26/2007
			09/14/2011		07/27/2011	
55	130th Street	Calumet River	09/13/2001	09/13/2002	08/24/2001	08/08/2003
			09/03/2002	08/04/2003	09/03/2002	07/27/2007
			08/08/2003	09/01/2004	08/08/2003	
			09/01/2004	09/28/2005	09/01/2004	
			09/28/2005	06/29/2006	09/28/2005	
			06/29/2006	09/06/2007	06/29/2006	
			09/06/2007	10/27/2008	07/27/2007	
			10/27/2008	07/23/2009	08/07/2008	
			07/23/2009		07/23/2009	
			08/11/2010		08/11/2010	
			09/08/2011		07/27/2011	
			09/12/2012			
56	Indiana Avenue	Little Calumet River North	09/26/2003	09/26/2003	07/14/2003	07/14/2003
			07/30/2007	07/30/2007	07/30/2007	07/30/2007
			09/15/2011		08/16/2011	
76	Halsted Street	Little Calumet River North	09/12/2001	09/16/2002	08/24/2001	07/11/2003
			09/16/2002	07/11/2003	09/16/2002	07/31/2007
			09/26/2003	09/30/2004	07/11/2003	
			09/30/2004	09/27/2005	09/30/2004	

TABLE 1 (Continued): SAMPLING DATES FOR AMBIENT WATER QUALITY MONITORING PROGRAM STATIONS IN THE CALUMET RIVER SYSTEM DURING 2001 THROUGH 2012

Station No.	Sampling Station	Waterway	Fish	Habitat Assessment	Benthic Invertebrates	Sediment Quality
76	Halsted Street	Little Calumet River North	09/27/2005	07/21/2006	09/27/2005	
			07/21/2006	07/31/2007	07/21/2006	
			07/31/2007	10/28/2008	07/31/2007	
			10/28/2008	07/30/2009	08/06/2008	
			07/30/2009		07/30/2009	
			08/19/2010		08/19/2010	
			09/21/2011		08/16/2011	
			09/10/2012			
57	Ashland Avenue	Little Calumet River South	08/18/2003	08/13/2003	08/13/2003	08/13/2003
			08/16/2007	08/16/2007	07/23/2007	07/23/2007
			09/06/2011	08/09/2011	08/05/2011	
52	Wentworth Avenue	Little Calumet River South	09/08/2003	09/08/2003	09/08/2003	09/03/2003
			09/11/2007	09/11/2007	07/23/2007	07/23/2007
			08/22/2011	08/22/2011	08/22/2011	
58	Ashland Avenue	Calumet-Sag Channel	09/05/2003	09/05/2003	09/05/2003	09/05/2003
			08/01/2007	08/01/2007	08/01/2007	08/01/2007
			08/18/2011		08/16/2011	
59	Cicero Avenue	Calumet-Sag Channel	09/14/2001	09/17/2002	08/24/2001	07/31/2003
			09/05/2002	07/31/2003	09/05/2002	08/02/2007
			07/31/2003	08/31/2004	07/31/2003	
			08/31/2004	08/29/2005	08/31/2004	
			09/29/2005	07/24/2006	08/29/2005	

TABLE 1 (Continued): SAMPLING DATES FOR AMBIENT WATER QUALITY MONITORING PROGRAM STATIONS IN THE CALUMET RIVER SYSTEM DURING 2001 THROUGH 2012

Station No.	Sampling Station	Waterway	Fish	Habitat Assessment	Benthic Invertebrates	Sediment Quality
59	Cicero Avenue	Calumet-Sag Channel	07/24/2006	08/02/2007	07/24/2006	
			08/02/2007	11/17/2008	08/02/2007	
			11/17/2008	07/14/2009	08/06/2008	
			07/14/2009		07/14/2009	
			08/13/2010		08/13/2010	
			08/03/2011		07/22/2011	
			08/30/2012			
43	Route 83	Calumet-Sag Channel	07/30/2003	07/30/2003	07/30/2003	07/30/2003
			09/14/2007	09/14/2007	08/09/2007	08/09/2007
			09/19/2011		07/26/2011	
86	Burnham Avenue	Grand Calumet River	09/03/2003	09/03/2003	09/03/2003	09/03/2003
			09/05/2007	09/05/2007	07/25/2007	07/25/2007
			08/10/2011	08/10/2011	08/10/2011	
50	Burnham Avenue	Indian Creek	07/01/2003	07/01/2003	07/01/2003	07/01/2003
			08/13/2007	08/13/2007	07/25/2007	07/25/2007
			07/15/2011	07/15/2011	07/15/2011	
97	170th Street	Thorn Creek	07/09/2003	07/09/2003	07/09/2003	07/08/2003
			09/05/2007	09/05/2007	07/24/2007	07/24/2007
			07/13/2011	07/13/2011	07/13/2011	

TABLE 1 (Continued): SAMPLING DATES FOR AMBIENT WATER QUALITY MONITORING PROGRAM STATIONS IN THE CALUMET RIVER SYSTEM DURING 2001 THROUGH 2012

Station No.	Sampling Station	Waterway	Fish	Habitat Assessment	Benthic Invertebrates	Sediment Quality
54	Joe Orr Road	Thorn Creek	08/12/2003 08/13/2007 07/14/2011	08/12/2003 08/13/2007 07/14/2011	08/12/2003 07/24/2007 07/14/2011	08/12/2003 07/24/2007

Calculating Chicago Area Waterway System Habitat Index Scores. LimnoTech used a process developed to create the Non-Wadeable Habitat Index for Michigan (Wilhelm et al., 2005) as the basis for the CAWS Habitat Index (LimnoTech, 2010). This process involved three major elements:

1. Sequential reduction of the list of habitat variables using qualitative screening, correlation analysis, and principle components analysis.

2. Identification of key habitat variables that best explain 2001- 2007 AWQMP CAWS fish data using multiple linear regression.

3. Incorporation of key habitat variables into an index that can be applied to measure variation and change in the system.

Using this process, the following variables were chosen to create the CAWS Habitat Index (CAWSHI): Maximum depth of channel (-), off-channel bays (+), vertical wall banks (-), riprap banks (-), manmade structures (-), macrophyte cover (+), overhanging vegetation (+), bank pocket areas (+), large substrate in shallow areas (+), large substrate in deep areas (+), organic sludge (-). Some of these variables have a positive biological correlation and some have a negative correlation (indicated here as + or -). These values were calculated and then normalized 0–100, with 100 being the best possible score. Fish data collected via the AWQMP between 2001 and 2007 were the main driver of the CAWSHI metrics with 48 percent of the variability explained by the CAWSHI (LimnoTech, 2010).

Sediment Chemistry

Sample Collection. Sediment samples were collected using a 6 x 6 inch Petite Ponar grab sampler (PP). Prior to sample collection, the PP and the metal and plastic pans and scoops used to process the materials were cleaned with hot water and laboratory detergent, rinsed with de-ionized water, and allowed to air dry. The PP and metal pans and scoops were then rinsed with acetone, allowed to air dry, and dried in an oven at 105°C for one hour. When dry and cool, each set was placed in a plastic bag and sealed to prevent contamination until ready for use. Sediment samples were collected from the center and side of the waterway using a separately cleaned PP at each sample site during the summer of 2003 and 2007. The sediment samples were transferred into plastic or metal pans and then put into the appropriate container using plastic or metal scoops. Sample containers are outlined in Table 2. Metal scoops and pans were used for samples collected in glass containers, whereas plastic scoops and pans were employed for sediment collected in plastic containers. The filled sample containers were placed on ice until they could be refrigerated.

Sample Analyses. The sediment samples were analyzed for total solids (TS), total volatile solids (TVS), ammonia nitrogen (NH_3-N), nitrite plus nitrate nitrogen ($NO_2 + NO_3$), total Kjeldahl nitrogen (TKN), total phosphorus (TP), total cyanide (TCN), phenols, total metals (including arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc), and organic priority pollutants (OPPs) (listed in Table 3) by the District's Analytical Laboratory Division. Additionally, a portion of the sediment samples were sent on ice to a contractor laboratory for Acid Volatile Sulfides (AVS) and Simultaneously Extracted Metals

TABLE 2: CONSTITUENTS ANALYZED, SAMPLE CONTAINERS, AND PRESERVATION METHODS FOR SEDIMENT SAMPLES COLLECTED FOR THE AMBIENT WATER QUALITY MONITORING PROGRAM

Constituents	Unit of Measure[1]	Sample Container	Preservative
Total Solids	percent	Glass	Cool, 4°C
Total Volatile Solids	percent	Glass	Cool, 4°C
Un-ionized Ammonia	mg/kg	Glass	Cool, 4°C
Nitrite plus Nitrate Nitrogen	mg/kg	Glass	Cool, 4°C
Total Kjeldahl Nitrogen	mg/kg	Glass	Cool, 4°C
Total Phosphorus	mg/kg	Glass	Cool, 4°C
Phenols	mg/kg	Glass	Cool, 4°C
Total Cyanide	mg/kg	Glass	Cool, 4°C
Acid Volatile Sulfide	µmoles/g	Plastic	Cool, 4°C
Simultaneously Extracted Metal	µmoles/g	Plastic	Cool, 4°C
Total Organic Carbon	mg/kg	Glass	Cool, 4°C
Particle Size	percent	Plastic	Cool, 4°C
Toxicity (survival)	percent	Plastic	Cool, 4°C
Toxicity (growth)	mg/organism[2]	Plastic	Cool, 4°C
Total Metals (Arsenic, Cadmium, Chromium Copper, Iron, Lead, Manganese, Mercury, Nickel, Silver, and Zinc)	mg/kg	Glass	Cool, 4°C
Organic Priority Pollutants (Volatile Organic Compounds, Polycyclic Aromatic Hydrocarbons, Polychlorinated Biphenyls, Pesticides)	µg/kg	Glass	Cool, 4°C

[1]Expressed on a dry-weight basis.

TABLE 3: LIST OF ORGANIC PRIORITY POLLUTANTS ANALYZED IN SEDIMENT SAMPLES COLLECTED FOR THE AMBIENT WATER QUALITY MONITORING PROGRAM DURING 2003 AND 2007

Volatile Organic Compounds	Acid Extractables	Base/Neutral Extractables	Pesticides and PCBs
Acrolein	2-Chlorophenol	Acenaphthene	Aldrin
Acrylonitrile	2,4-Dichlorophenol	Acenaphthylene	a-BHC-alpha
Benzene	2,4-Dimethylphenol	Anthracene	b-BHC-beta
Bromoform	4,6-Dinitro-o-cresol	Benzidine	BHC-gamma
Carbon tetrachloride	2,4-Dinitrophenol	Benzo(a)anthracene	BHC-delta
Chlorobenzene	2-Nitrophenol	Benzo(a)pyrene	Chlordane
Chlorodibromomethane	4-Nitrophenol	3,4-Benzofluoranthene	4,4'-DDT
Chloroethane	Parachlorometacresol	Benzo(ghi)perylene	4,4'-DDE
2-Chloroethylvinyl ether	Pentachlorophenol	Benzo(k)fluoranthene	4,4'-DDD
Chloroform	Phenol	Bis(2-chloroethoxy)methane	Dieldrin
Dichlorobromomethane	2,4,6-Trichlorophenol	Bis(2-chloroethyl)ether	a-Endosulfan-alpha
1,1-Dichloroethane		Bis(2-chloroisopropyl)ether	b-Endosulfan-beta
1,2-Dichloroethane		Bis(2-ethylhexyl)phthalate	Endosulfan sulfate
1,1-Dichloroethylene		4-Bromophenyl phenyl ether	Endrin
1,2-Dichloropropane		Butylbenzyl phthalate	Endrin aldehyde
1,3-Dichloropropene		2-Chloronaphthalene	Heptachlor
Ethyl benzene		4-Chlorophenyl phenyl ether	Heptachlor epoxide
Methyl bromide		Chrysene	PCB-1242
Methyl chloride		Dibenzo(a,h)anthracene	PCB-1254
Methylene chloride		1,2-Dichlorobenzene	PCB-1221
1,1,2,2-Tetrachloroethane		1,3-Dichlorobenzene	PCB-1232
Tetrachloroethylene		1,4-Dichlorobenzene	PCB-1248
Toluene		3,3-Dichlorobenzidine	PCB-1260
1,2-trans-Dichloroethylene		Diethyl phthalate	PCB-1016
1,1,1-Trichloroethane		Dimethyl phthalate	Toxaphene
1,1,2-Trichloroethane		Di-n-butyl phthalate	

TABLE 3 (Continued): LIST OF ORGANIC PRIORITY POLLUTANTS ANALYZED IN SEDIMENT SAMPLES COLLECTED FOR THE AMBIENT WATER QUALITY MONITORING PROGRAM DURING 2003 AND 2007

Volatile Organic Compounds	Acid Extractables	Base/Neutral Extractables	Pesticides and PCBs
Trichloroethylene		2,4-Dinitrotoluene	
Vinyl chloride		2,6-Dinitrotoluene	
Trichlorofluoromethane		Di-n-octyl phthalate	
		1,2-Diphenylhydrazine	
		Fluoranthene	
		Fluorene	
		Hexachlorobenzene	
		Hexachlorobutadiene	
		Hexachlorocyclopentadiene	
		Hexachloroethane	
		Indeno(1,2,3-cd)pyrene	
		Isophorone	
		Naphthalene	
		Nitrobenzene	
		N-Nitrosodimethylamine	
		N-Nitrosodi-n-propylamine	
		N-Nitrosodiphenylamine	
		Phenanthrene	
		Pyrene	
		1,2,4-Trichlorobenzene	

(SEM) analyses, and for physical characterization analyses for total organic carbon (TOC) and particle size. The constituents analyzed in sediment, sample containers used, and preservation methods are summarized in Table 2. In the laboratory, all constituents were analyzed using procedures established by the United States Environmental Protection Agency (USEPA) or described in *Standard Methods for the Examination of Water and Wastewater* (19^{th} Edition, 1998).

Statistical Analysis. The mean and maximum values for each measured parameter were calculated. When a result was reported as less than a specific limit the actual limit value was used for statistical analysis. A select group of parameters including some metals and some organic compounds were compared to consensus based numerical SQGs (MacDonald 2000).

Sediment Toxicity

Sample Collection. Sediment samples were collected using a clean 6 x 6 inch PP from the center and side of the waterways, and scooped into 1-gallon plastic buckets (at least ½ full). Buckets were kept on ice until they could be refrigerated.

Sample Analysis. The sediment samples were sent in coolers on ice to a contractor for ten-day *Chironomus tentans* toxicity testing (USEPA 2000 Test Method 100.2). Tests were performed within 14 days of sediment collection.

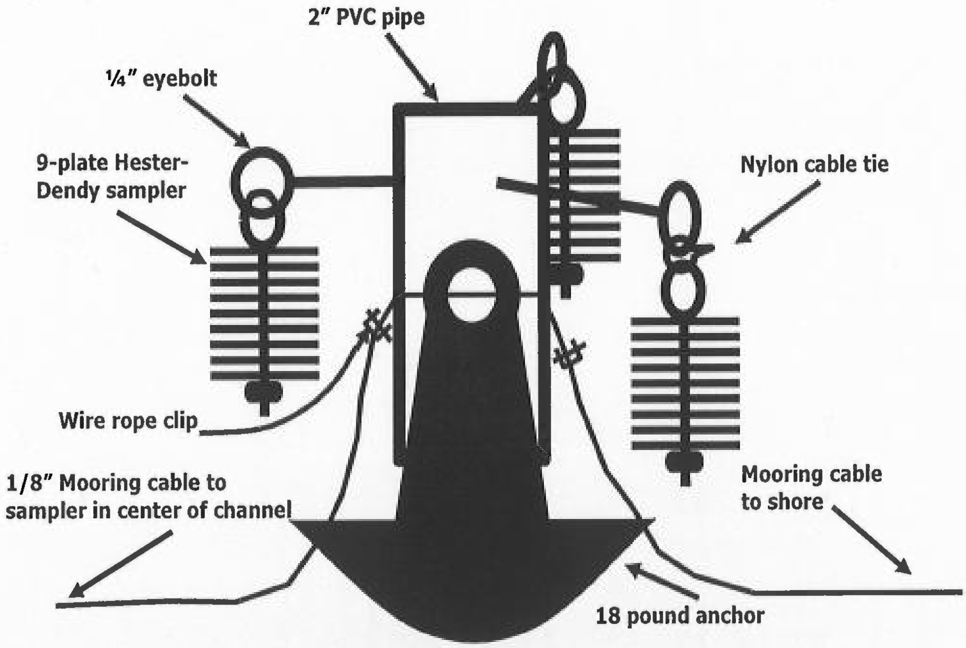
Statistical Analysis. The percentage of samples showing toxicity in respect to organism survival and growth were calculated.

Benthic Invertebrates

Ponar Sediment Sampling. Triplicate sediment samples were collected with a PP (0.023 m^2) from the center and one side of the deep draft and wadeable waterway stations. These stations include 130^{th} Street, Halsted Street, and Cicero Avenue which were sampled annually from 2001–2010. Also included are Ewing Avenue, Wentworth Avenue on the Little Calumet River South (Wentworth Avenue), Ashland Avenue on the Little Calumet River South (Ashland LCR-S), and Indiana Avenue, Route 83, Joe Orr Road on Thorn Creek (Joe Orr), and 170^{th} Street, Burnham Avenue on Indian Creek (Burnham IC), and Burnham GCR. These stations were sampled only in 2003 and 2007. Grab samples were taken at locations upstream from any prior sampling disturbance, such as HD retrievals (see description in next section), to avoid collecting disturbed sediment. An appropriate area for sampling with a PP was chosen by a staff biologist to avoid obstructions such as large rocks or plants. The sediment samples were sieved in the field using a field-sieving bucket with 250 micrometer (μm) openings. The sieved material was poured into one-gallon plastic containers, preserved in a 10 percent formalin solution, and brought back to the laboratory for analysis. All samples were stored at 4°C until processed.

Artificial Substrate Sampling. HD artificial substrate samplers were deployed at each station between May and June. Figure 2 shows a diagram of the plate configuration that was assembled prior to deployment in the waterways. A total of 27 3 x 3 inch sampling plates were attached to each 18-pound river anchor, connected to an object on shore (usually a tree) and

FIGURE 2: CONFIGURATION OF HESTER DENDY LARVAL PLATE SAMPLER



tethered to another HD assembly by a cable. The HD assemblies were then placed on the bottom of the waterway, one in the center and the other on one side. Sampling locations and frequency coincide with PP sampling. These substrates were left in the waterway for an average of seven weeks and then retrieved at the time of other biological sampling. The HD samplers were located and the anchors were lifted out of the waterway with a 250 μm mesh plankton net underneath to avoid organism loss at the water surface. The plates were then cut from the anchors and placed into a one-gallon bucket with a secure, leak-proof lid. Invertebrates from the plankton net reservoir were also rinsed into the buckets, which were then filled with river water and brought to a 10 percent final concentration of formalin. These samples were then brought to the laboratory and stored at 4°C until processed.

Benthic Invertebrate Processing. Samples were fixed in formalin for thirty days. Next, the Ponar sediment samples were gently washed with water and screened through a United States Standard number 60 mesh (250 μm) sieve and transferred to a 70 percent ethanol solution. Each HD plate was removed from the sampler and gently brushed with a paintbrush on both sides while under a slow stream of running water in order to rinse the attached invertebrates into the sieve. The formalin solution remaining in the HD sample container was rinsed into the sieve in order to capture any invertebrates that fell from the HD plates. The contents of this sieve were then rinsed back into the bucket with a 70 percent ethanol solution. The PP and HD samples were then stored at 4°C until processed. Before processing, the samples were sieved to remove the ethanol solution. The sieved material was then examined in small batches under a compound microscope in a 100 x 50 mm glass crystallizing dish filled about one cm high. We then counted oligochaete worms and removed all other invertebrates from the finer residual material. In situations where large numbers of any one taxon (usually worms) were encountered (>3000), their abundance was estimated using a sub-sampling device. Invertebrates, besides worms, were sent to a consultant (EA Engineering) for identification to genus or species, when possible.

Hilsenhoff Biotic Index. The HBI estimates the overall tolerance of the benthic community in a sample area, weighted by the relative abundance of each taxonomic group. Organisms are assigned a tolerance number from 0 to 10 depending on that taxonomic group's known sensitivity to organic pollutants, 0 being the most sensitive and 10 being the most tolerant.

The HBI is an average of tolerance values for all individuals collected from a site. It is calculated by multiplying the tolerance value by the number of specimens in that taxonomic group. This is done for each taxonomic group in the sample. The sum of the products is then divided by the total number of specimens in the sample. This is expressed by the following equation:

$$HBI = \frac{\sum ni \times ai}{N}$$

Where

n = the number of specimens in taxa i.
a = the tolerance value of taxa i.
N = the total number of specimens in the sample.

Sites were then classified as Excellent, Very Good, Good, Fair, Fairly Poor, Poor, or Very Poor. The classification ranges are as follows:

Biotic Index	Water Quality	Degree of Organic Pollution
0.00–3.50	Excellent	No apparent organic pollution
3.51–4.50	Very Good	Possible slight organic pollution
4.51–5.50	Good	Some organic pollution
5.51–6.50	Fair	Fairly significant organic pollution
6.51–7.50	Fairly Poor	Significant organic pollution
7.51–8.50	Poor	Very significant organic pollution
8.51–10.00	Very Poor	Severe organic pollution

It should be noted that the HBI was designed to evaluate streams with rock or gravel riffles. Use of this index is not recommended for slow flowing, silt-bottomed streams, such as some of the CRS. However, since an appropriate macroinvertebrate index for large rivers does not exist for Illinois, the HBI was used to assess the relative condition of macroinvertebrate communities at the CRS stations.

Fish

Boatable Stream Sampling. Fish were collected at each sampling station using a boat-mounted electrofisher powered by a generator. Stunned fish were picked out of the water with long-handled dip nets. For deep draft sites, the section of canal sampled extended for 400 meters. For Burnham GCR, Wentworth Avenue, and 170th Street, a 100 meter section of waterway was sampled with a fourteen-foot (small) electrofishing boat instead of the sixteen-foot (large) electrofishing boat. A 200-meter section of Ashland LCR-S was sampled using the small electrofishing boat. Whenever possible, both sides of the waterways were electrofished.

The large boat was not used to sample 130th Street, Cicero Avenue, and Halsted Street in 2008 because the generator had mechanical problems. Besides boat length and width, the main difference between the two boats was the size of the electrofisher. The small electrofishing boat had a 2.5 generator-powered pulsator (GPP) that had a target output range of five to seven amps, and the large electrofishing boat had a 5.0 GPP that had a target output range of 12 to 14 amps.

Wadeable Stream Sampling. Fish were collected at Joe Orr and Burnham IC using a DC backpack electrofisher and a bag seine. Conductivity and temperature (°C) were recorded before each sample collection. In most instances, two 40-meter long backpack electrofisher collections were conducted at each station. A 40-meter reach of the creek was electrified by moving upstream parallel to the bank. Additional personnel followed the electrofisher collecting the stunned fish with dip nets. Following the first collection, a second 40-meter electrofishing survey was conducted on the opposite bank. The total electrofishing time during each 40-meter collection was noted.

A 15-foot bag seine with 3/16-inch mesh was also used to collect fish. Staff pulled the seine for 40 meters traveling upstream parallel to the bank. Only two stations were sampled with a seine in the CRS (Joe Orr and Burnham IC). A total of five seine hauls were completed at these stations combined between 2001 and 2012. Each station had one seine haul which yielded zero fish.

Fish Processing. In the field, most fish were identified to species, weighed to the nearest gram or nearest 0.1 gram (depending on size), measured for standard and total length to the nearest millimeter, and examined for the incidence of disease, parasites, or other anomalies. Following processing, these fish were returned live to the river. Minnows and other small fish that were difficult to identify were preserved in a 10 percent formalin solution and returned to the laboratory for further analysis. These fish were processed in a similar manner to the field-measured fish except that they were weighed to the nearest 0.01 gram.

Index of Biotic Integrity. Biological integrity of aquatic ecosystems is the ability to support and maintain a balanced, integrated, and adaptive community having a species composition, diversity, and functional organization comparable to that of a natural habitat (Karr et al., 1986). Karr's 1986 IBI was used to analyze fish data.

The limitations of using this tool to assess man-made and large channelized waterways in the Chicago area should be recognized, because this index was designed to measure the integrity of small wadeable streams. Karr's IBI integrates information from 12 fish community metrics that fall into three major categories: (1) species richness and composition, (2) trophic composition, and (3) fish abundance and condition. Each metric is scored 1, 3, or 5 based on whether its evaluation deviates strongly, deviates somewhat, or approximates expectations, respectively, as compared to an undisturbed site located in a similar geographical region and on a stream of comparable size. Individual metrics are added to calculate a total IBI score. A high IBI indicates high biological integrity or health and low disturbance or lack of perturbations. A low IBI indicates low biological integrity and high disturbance or degradation. Separate IBI metric scores were determined based on the relative abundance of fish collected with each fishing gear, but only IBI scores calculated from electrofishing methods are discussed in this report. IBI categories of Good (41–60), Fair (21–40), or Poor (<21) were determined, as derived by the IEPA (IEPA, 1996).

Statistical Analyses of Water Quality Data

In addition to biological, habitat, and sediment monitoring, the District performs AWQM and CDOM in District service area waterways. Given that water quality can impact biological communities, the available data were analyzed to identify any trends in key water quality parameters between 2001 and 2012. Since biological monitoring was performed at AWQM stations, the available water quality data was used from all of these locations. Hourly CDOM data was analyzed at stations from the Calumet River, LCR-S, LCR-N, GCR, and CSC.

ANOVA and the Mann-Kendall methods were utilized to identify annual differences and trends in TSS, NH_3-N, and DO. The objective of the ANOVA was to identify the yearly population characteristics of these parameters for each monitoring location. If the ANOVA test showed that the yearly population parameters were the same, we concluded that there was no significant difference among the yearly data, and the effect of these parameters on the biological community did not change during the study period. The Mann-Kendall method was used to determine whether there was a positive, negative or no trend for each parameter between 2001 and 2012.

RESULTS

Habitat

Table 4 displays the QHEI scores and ratings for the six wadeable stations in the CRS assessed in 2011. Table 5 shows the CAWS Habitat Index scores for the eight navigable stations in the CRS in 2008. A summary of the individual metric scores for the QHEI and CAWS Habitat Index scores is provided in Figures 3 and 4, respectively. The data in Figure 3 shows that there was not much variability measured among the wadeable stations in the CRS. In the QHEI assessment of the wadeable stations, morphology, substrate, and in-stream cover were parameters that scored low but had the largest potential impact on the overall score (20 percent each).

Although the navigable stations of the CRS are all highly impacted by urbanization, there were metrics that had a combined effect of making some areas more suitable for aquatic life (Figure 4). The lack of riprap banks at Cicero Avenue and Halsted Street, the presence of off channel bays at Halsted Street, fewer vertical wall banks at Cicero Avenue, less depth at Halsted Street and fewer manmade structures at Indiana Avenue and Halsted Street combined to make Halsted Street, Indiana Avenue and Cicero Avenue the three highest scoring stations (1, 2, 3, respectively). The most variable metrics in the CAWS were riprap banks, manmade structures, off channel bays, vertical wall banks and organic sludge composition each with a standard deviation of 5.63, 3.64, 2.32, 1.95 and 1.2, respectively. The remaining metrics had standard deviations less than one.

Sediment Chemistry

Sediment quality can considerably impact overlying water quality, benthic community structure, food chain dynamics, and other elements of freshwater ecosystems. Since sediment acts as a reservoir for persistent or bioaccumulative contaminants, sediment data reflects a long-term record of quality. Some of the sources of pollutants that contaminate river sediments include direct input from industrial and municipal waste dischargers, polluted runoff from urban and agricultural areas, and atmospheric deposition (USEPA, 2001). It should be noted that grab sample sediment data can be difficult to interpret, as samples may reflect a "hot spot," or an area with an unusually high concentration of a specific pollutant. This can be caused by an accidental release or spill of a contaminant that sinks down through the water column and resides in the sediment. Similarly, sediment chemistry can vary widely between the side and center of the channel at the sampling location. Therefore, assessing sediment quality based on a limited number of samples is difficult. The maximum number of data points for each CRS sampling site was only four, so detailed statistical analysis was not practical. Side and center samples were collected at each site (where possible), but sediment chemistry data did not yield any clearly identified spatial or temporal patterns in most of the CRS, because concentrations were variable within each station and among sampling locations. Side and center sample results were averaged for each year and the maximum result for each year was determined to give a more representative result for each site.

TABLE 4: SUMMARY OF QUALITATIVE HABITAT EVALUATION INDEX SCORES FOR CALUMET RIVER SYSTEM WADEABLE SAMPLING STATIONS DURING 2011

Station No.	Station Name	Waterway	QHEI Score	Habitat Rating
58	Ashland Avenue	Little Calumet River	61	Good
50	Burnham Avenue	Indian Creek	51	Fair
86	Burnham Avenue	Grand Calumet River	36	Poor
52	Wentworth Avenue	Little Calumet River	33	Poor
97	170th Street	Thorn Creek	46	Fair
54	Joe Orr Road	Thorn Creek	70	Good

TABLE 5: SUMMARY OF CHICAGO AREA WATERWAY SYSTEM HABITAT INDEX SCORES FOR DEEP DRAFT SAMPLING STATIONS IN THE CALUMET RIVER SYSTEM DURING 2008

Station No.	Station Name	Waterway	Normalized Score
43	Route 83	Cal Sag Channel	33
S3	Palos Hills	Cal Sag Channel	46
S4	Worth & Palos Heights	Cal Sag Channel	38
S5	Alsip	Cal Sag Channel	39
58	Ashland Ave	Cal Sag Channel	36
59	Cicero Ave	Cal Sag Channel	49
56	Indiana Ave	Little Calumet River North	53
76	Halsted St	Little Calumet River North	67

FIGURE 3: INDIVIDUAL QUALITATIVE HABITAT EVALUATION INDEX METRIC SCORES FOR WADEABLE SAMPLING STATIONS IN THE CALUMET RIVER SYSTEM DURING 2011

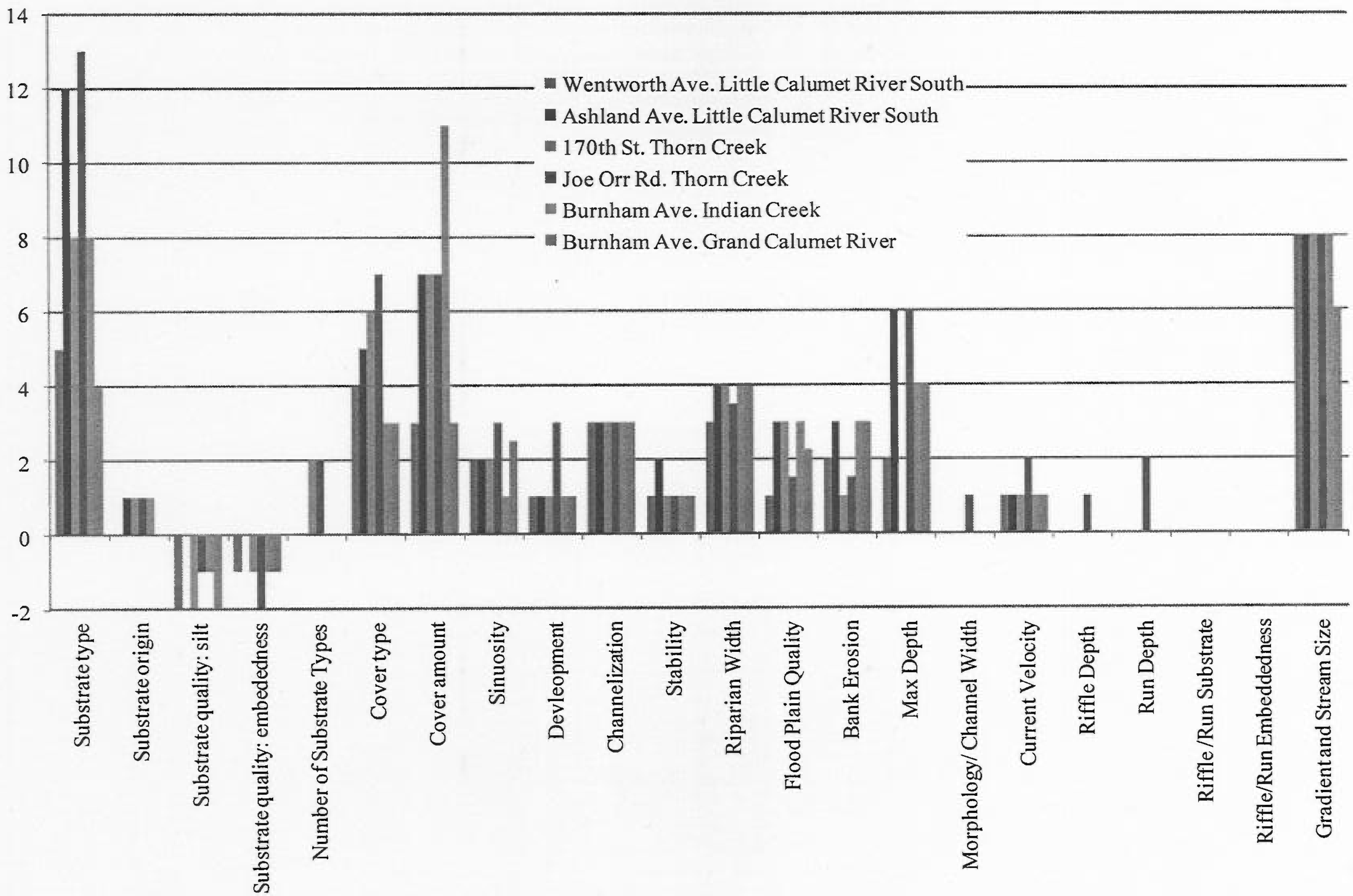
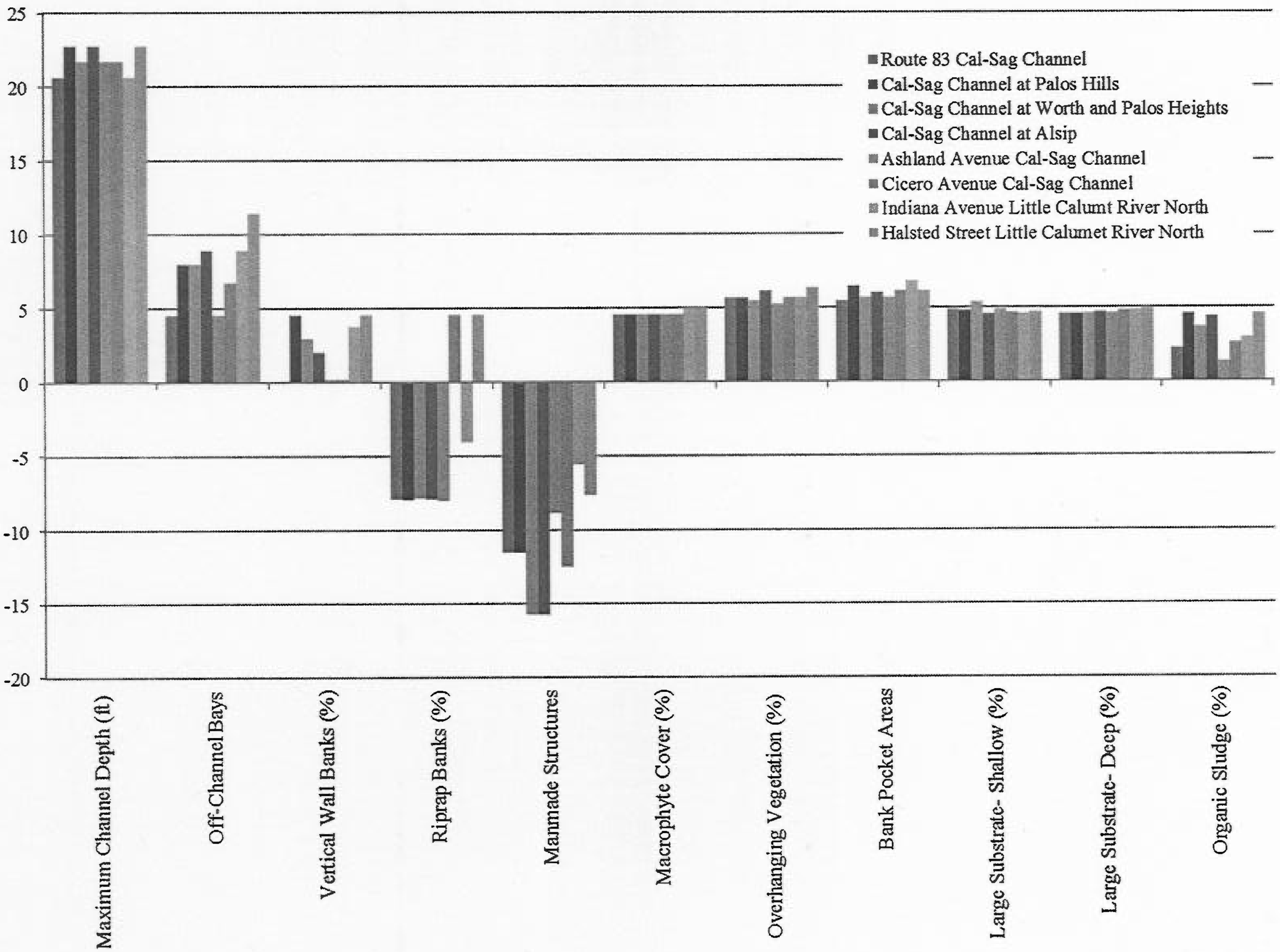


FIGURE 4: INDIVIDUAL CHICAGO AREA WATERWAY SYSTEM HABITAT INDEX METRIC SCORES FOR DEEP DRAFT SAMPLING STATIONS IN THE CALUMET RIVER SYSTEM DURING 2008



General Chemistry. The concentrations of the eight general chemistry constituents measured in sediment from the side and center at each of the 13 sample sites during individual years are presented in previous reports for the years 2003 and 2007 (Wasik et al. 2008 and Gallagher et al. 2011).

For this report, the maximum and mean concentrations of each constituent were calculated for each sampling station for each year and are presented in Appendix BI. All the tables show the results from an upstream to downstream perspective along the x-axis. There were no definite spatial patterns in most of the CRS, but some of the chemical parameters showed higher levels in the downstream segments of some of the waterways.

Trace Metals. The 11 measured trace metal concentrations for these same stations during individual years are presented in previous reports for 2003 and 2007 (Wasik et al. 2008 and Gallagher et al. 2011). The maximum and mean concentrations of each constituent were calculated for each sampling station for each year and are presented in Appendix BII.

The total arsenic results were always below the detection and reporting limits, so statistical analysis was not done. Burnham GCR often had the highest concentration of the trace metals analyzed.

Acid Volatile Sulfide, Simultaneously Extracted Metals, Total Organic Carbon, and Particle Size. The AVS, SEM, TOC, and particle size data for 13 CRS sampling stations during individual years are presented in previous reports for 2003 and 2007 (Wasik et al. 2008 and Gallagher et al. 2011). The maximum and mean concentrations of each constituent were calculated for each sampling station for each year and are presented in Appendix BIII. The ratio of SEM to AVS can affect the bioavailability of divalent metals for which sulfide ions have a high affinity. For instance, if AVS is greater than SEM concentration, it is less likely that metals are available for biological uptake, thus rendering them less toxic to organisms. If the ratio is greater than one, the sediment is potentially toxic to organisms. Particle size is a useful analysis since it influences chemical reactions in the sediment and the type of invertebrate taxa that will colonize the substrate (USEPA, 2001). Sediment particle size was variable throughout the CRS.

Three of the monitoring stations, Ewing Avenue, 130th Street, and Indiana Avenue, had a mean SEM to AVS ratio of one or greater, and Joe Orr, 170th Street, Ashland LCR-S, Ewing Avenue, 130th Street, and Indiana Avenue had maximum ratios of greater than one, suggesting the sediment may be potentially toxic to aquatic organisms (Table BIII-1). Burnham IC had the highest concentration of TOC in the CRS, and the overall trend showed an increase in TOC concentrations in the downstream direction for some of the other CRS waterways (Table BIII-2).

Organic Priority Pollutants. A total of 111 OPPs were analyzed in the samples collected. The concentrations of OPPs detected in the side and center sediment samples collected at each site during individual years are presented in previous reports for 2003 and 2007 (Wasik et al. 2008 and Gallagher et al. 2011). The maximum and mean of values for total PAHs, PCBs, and selected pesticides were calculated for each sampling station and year are presented in Appendix BIV. Stations on the CSC had the highest values in the deep draft waterways, while stations on Thorn Creek and Burnham GCR showed the highest values for the wadeable waterways.

Sediment Quality Guidelines. Consensus-based SQGs were derived for 28 common COC in freshwater sediments as a tool to assess contaminated sediments (MacDonald, 2000). The COC included various metals, PAHs, PCBs, and organochlorine pesticides. Two effect level concentrations were identified for each substance: a threshold effect concentration (TEC) and a PEC. Concentrations below the TEC indicate no potential for adverse effects on sediment-dwelling organisms. Concentrations above the PEC indicate that adverse effects on sediment-dwelling organisms are likely. The mean and maximum concentrations of the COC detected in CRS sediment samples in 2003 and 2007 were compared to the TEC and PEC concentrations and the total number of incidents below or above the respective concentrations are presented in Tables 6 through 9.

The three sites with the highest incidence of concentrations above the PEC were Cicero Avenue, Route 83, and Burnham GCR. Joe Orr and Burnham IC had the highest count of concentrations below the TEC.

Sediment Toxicity

Sediment toxicity analysis demonstrates whether sediment is conducive to organism growth and survival. The toxicity data resulting from the *Chironomus tentans* ten-day toxicity tests for each sediment sample collected from the side and center of each sample site are presented in previous reports for 2003 and 2007 (Wasik et al. 2008 and Gallagher et al. 2011). The percentage of samples that exhibited significant toxicity based on overall survival and growth of the organism is shown in Figure 5. A significant difference in *Chironomus* survival compared to the control sediment indicated that the collected sediment constituted an unsuitable habitat for *Chironomus* survival. A significant difference in *Chironomus* dried weight and or *Chironomus* ash-free dried weight compared to the control sediment indicated that the collected sediment constituted an unsuitable habitat for optimal *Chironomus* growth.

The stations showing the highest percentage of toxicity were in the downstream portions of the deep draft CRS. Burnham GCR showed the highest percentage of toxicity compared to the other wadeable stations in the CRS. Joe Orr was the only station that showed no toxicity.

Benthic Macroinvertebrates

The HD and PP samples from the CRS between 2001 and 2010 yielded 110 total taxa, including 12 relatively pollution sensitive Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa. Total and EPT taxa richness, expressed as HBI scores, are summarized by waterway in Figure 6. There was not much difference in taxa richness between the waterways. Chironomidae was the most taxa-rich group with 50 taxa (data not shown). Among the EPT, Trichoptera was the most speciose group with seven taxa, followed by Ephemeroptera with four taxa, and Plecoptera with only a single taxon.

Appendix C presents a table showing the benthic macroinvertebrate community composition by waterway. The benthic community in the CRS largely consisted of tolerant taxa. Six of the seven waterways in the CRS were dominated by Annelida. The Calumet River (Table C-1) was dominated by Bivalvia (zebra and quagga mussels). Although the annual data is not

TABLE 6: OCCURRENCES BELOW THRESHOLD EFFECT CONCENTRATION VALUES IN SEDIMENTS COLLECTED AT WADEABLE STATIONS IN THE CALUMET RIVER SYSTEM DURING 2003 AND 2007

Constituent	Statistic	TEC[1]	Wentworth Avenue Little Calumet River South	Joe Orr Road Thorn Creek	170th Street Thorn Creek	Ashland Avenue Little Calumet River South	Burnham Avenue Grand Calumet River	Burnham Avenue Indian Creek
Cr^2	Mean	<43		Y	Y	Y		Y
Cr^2	Max	<43		Y	Y	Y		Y
Cu^2	Mean	<32		Y	Y			Y
Cu^2	Max	<32		Y	Y	Y		Y
Pb^2	Mean	<36		Y				
Hg^2	Mean	<0.180		Y		Y		Y
Hg^2	Max	<0.180		Y				
Ni^2	Mean	<23		Y	Y			Y
Ni^2	Max	<23		Y				Y
Total PCBs[3]	Mean	<59.8						Y
Total PCBs[3]	Max	<59.8						Y
Sum DDD[3]	Mean	<4.88		Y				
Sum DDT[3]	Mean	<4.16		Y				
Number of occurrences less than TEC			0	11	5	4	0	10

[1]TEC = Threshold Effect Concentration.
[2]Results reported in mg/kg.
[3]Results reported in µg/kg.

TABLE 7: OCCURRENCES BELOW THRESHOLD EFFECT CONCENTRATION VALUES IN SEDIMENTS COLLECTED AT DEEP DRAFT STATIONS IN THE CALUMET RIVER SYSTEM DURING 2003 AND 2007

Constituent	Statistic	TEC[1]	Ewing Avenue	130th Street	Indiana Avenue	Halsted Street	Ashland Avenue	Cicero Avenue	Route 83
			Calumet River	Calumet River	Little Calumet River North	Little Calumet River North	Calumet-Sag Channel	Calumet-Sag Channel	Calumet Sag Channel
Cr[2]	Mean	<43	Y	Y			Y		
Cr[2]	Max	<43	Y						
Cu[2]	Mean	<32		Y					
Cu[2]	Max	<32							
Pb[2]	Mean	<36							
Hg[2]	Mean	<0.180	Y	Y					
Hg[2]	Max	<0.180	Y	Y					
Ni[2]	Mean	<23		Y		Y	Y		
Ni[2]	Max	<23							
Total PCBs[3]	Mean	<59.8							
Total PCBs[3]	Max	<59.8							
Sum DDD[3]	Mean	<4.88	Y	Y		Y	Y		
Sum DDT[3]	Mean	<4.16	Y				Y		Y
Number of occurrences less than TEC			6	6	0	2	4	0	1

[1]TEC = Threshold Effect Concentration.
[2]Results reported in mg/kg.
[3]Results reported in µg/kg.

TABLE 8: OCCURRENCES BELOW PROBABLE EFFECT CONCENTRATION VALUES IN SEDIMENTS COLLECTED AT WADEABLE STATIONS IN THE CALUMET RIVER SYSTEM DURING 2003 AND 2007

Constituent	Statistic	PEC[1]	Wentworth Avenue Little Calumet River South	Joe Orr Road Thorn Creek	170th Street Thorn Creek	Ashland Avenue Little Calumet River South	Burnham Avenue Indian Creek	Burnham Avenue Grand Calumet River
Cd[2]	Mean	>5.0						Y
Cd[2]	Max	>5.0						Y
Cr[2]	Mean	>111						Y
Cr[2]	Max	>111						Y
Cu[2]	Mean	>149						Y
Cu[2]	Max	>149						Y
Pb[2]	Mean	>128						Y
Pb[2]	Max	>128						Y
Hg[2]	Mean	>1.060						Y
Hg[2]	Max	>1.060						Y
Ni[2]	Max	>49						Y
Zn[2]	Mean	>459						Y
Zn[2]	Max	>459						Y
Total PAHs[3]	Mean	>22,800	Y					Y
Total PAHs[3]	Max	>22,800	Y			Y		Y
Total PCBs[3]	Mean	>676			Y			
Total PCBs[3]	Max	>676		Y	Y			Y
Sum DDD[3]	Mean	>28			Y	Y		Y
Sum DDD[3]	Max	>28			Y	Y	Y	Y
Sum DDE[3]	Mean	>31.3						
Sum DDE[3]	Max	>31.3						Y

TABLE 8 (Continued): OCCURRENCES BELOW PROBABLE EFFECT CONCENTRATION VALUES IN SEDIMENTS COLLECTED AT WADEABLE STATIONS IN THE CALUMET RIVER SYSTEM DURING 2003 AND 2007

Constituent	Statistic	PEC[1]	Wentworth Avenue Little Calumet River South	Joe Orr Road Thorn Creek	170th Street Thorn Creek	Ashland Avenue Little Calumet River South	Burnham Avenue Indian Creek	Burnham Avenue Grand Calumet River
Sum DDT[3]	Mean	>62.9						Y
Sum DDT[3]	Max	>62.9					Y	Y
Number of occurrences greater than PEC			2	1	4	3	2	21

[1]PEC = Probable Effect Concentration.
[2]Results reported in mg/kg.
[3]Results reported in µg/kg.

TABLE 9: OCCURRENCES BELOW PROBABLE EFFECT CONCENTRATION VALUES IN SEDIMENTS COLLECTED AT DEEP DRAFT STATIONS IN THE CALUMET RIVER SYSTEM DURING 2003 AND 2007

Constituent	Statistic	PEC[1]	Ewing Avenue Calumet River	130th Street Calumet River	Indiana Avenue Little Calumet River North	Halsted Street Little Calumet River North	Ashland Avenue Calumet-Sag Channel	Cicero Avenue Calumet-Sag Channel	Route 83 Calumet-Sag Channel
Cd[1]	Mean	>5.0							
Cd[1]	Max	>5.0							Y
Cr[1]	Mean	>111							
Cr[1]	Max	>111				Y			Y
Cu[1]	Mean	>149							
Cu[1]	Max	>149							
Pb[1]	Mean	>128			Y	Y	Y	Y	Y
Pb[1]	Max	>128			Y	Y	Y	Y	Y
Hg[1]	Mean	>1.060			Y				
Hg[1]	Max	>1.060			Y				
Ni[1]	Max	>49							
Zn[1]	Mean	>459						Y	Y
Zn[1]	Max	>459		Y	Y			Y	Y
Total PAHs[2]	Mean	>22,800					Y	Y	
Total PAHs[2]	Max	>22,800			Y	Y	Y	Y	
Total PCBs[2]	Mean	>676		Y				Y	Y
Total PCBs[2]	Max	>676	Y	Y	Y		Y	Y	Y
Sum DDD[2]	Mean	>28						Y	
Sum DDD[2]	Max	>28						Y	Y
Sum DDE[2]	Mean	>31.3						Y	Y
Sum DDE[2]	Max	>31.3						Y	Y

TABLE 9 (Continued): OCCURRENCES BELOW PROBABLE EFFECT CONCENTRATION VALUES IN SEDIMENTS COLLECTED AT DEEP DRAFT STATIONS IN THE CALUMET RIVER SYSTEM DURING 2003 AND 2007

Constituent	Statistic	PEC[1]	Ewing Avenue	130th Street	Indiana Avenue	Halsted Street	Ashland Avenue	Cicero Avenue	Route 83
			Calumet River	Calumet River	Little Calumet River North	Little Calumet River North	Calumet-Sag Channel	Calumet-Sag Channel	Calumet-Sag Channel
Sum DDT[2]	Mean	>62.9							
Sum DDT[2]	Max	>62.9							
Number of occurrences greater than PEC			1	3	7	4	5	12	11

[1]PEC = Probable Effect Concentration.
[2]Results reported in mg/kg.
[3]Results reported in µg/kg.

FIGURE 5: PERCENTAGE OF SEDIMENT SAMPLES FROM STATIONS IN THE CALUMET RIVER SYSTEM THAT SHOWED GROWTH OR SURVIVAL RATES SIGNIFICANTLY LESS THAN CONTROL SITES DURING 2003 AND 2007

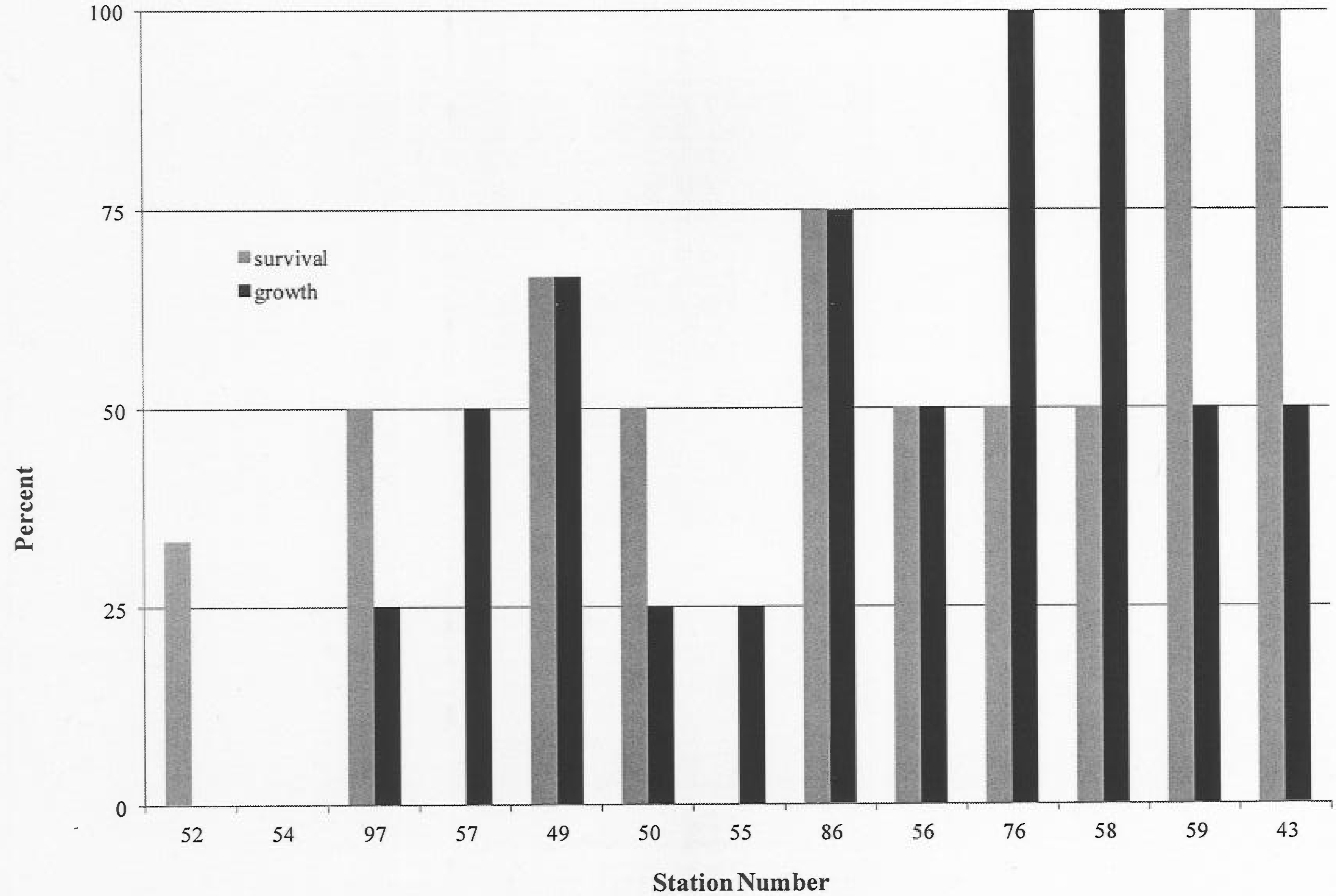
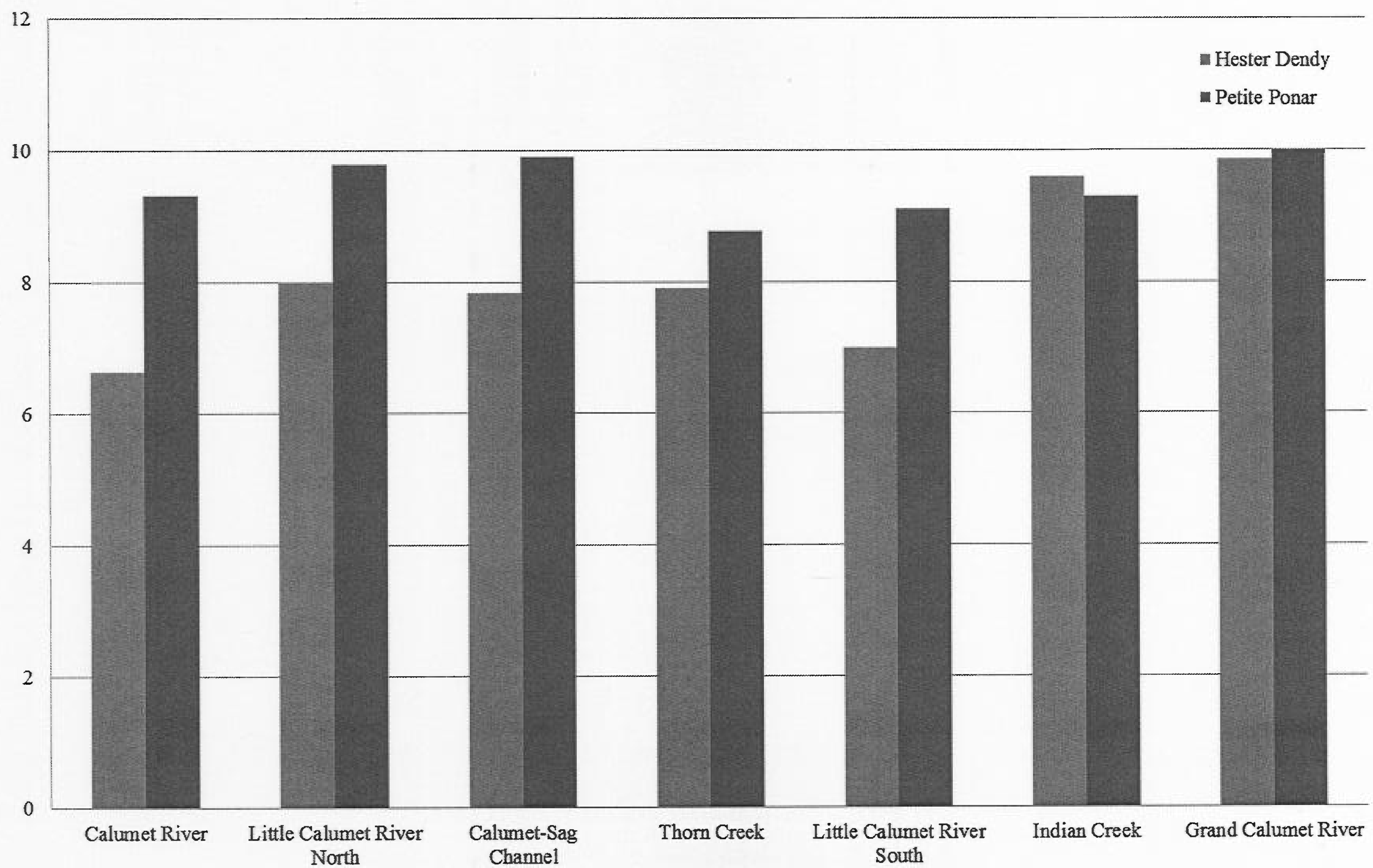


FIGURE 6: MEAN HILSENHOFF BIOTIC INDEX SCORES OF WATERWAYS IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2010



shown in Appendix C, between 2001 and 2006, Bivalvia was mostly represented by the invasive zebra mussel (*Dreissena polymorpha*). However, between 2007 and 2010 there was an introduction and shift toward dominance of the invasive quagga mussel (*Dreissena rostriformis bugensis*).

Hilsenhoff Biotic Index. The mean HBI scores ranged from 6.6 (Calumet River) to 9.9 (GCR) for HD samples and 8.8 (Thorn Creek) to 10.0 (GCR) for the PP samples (Figure 6). The HD samples have lower (pollution sensitive) scores because the samplers are designed to be selective for organisms living in the water column, as opposed to PP samplers which are designed to sample organisms living within the sediment. The more sensitive organisms, such as the EPT taxa, tend to live on substrates in the water column, improving the overall HBI score. The HBI scores in the CRS fall into the Poor (7.51–8.5) and Fairly Poor (6.51–7.5) categories. The high PP scores can be attributed to the dominance of tolerant organisms such as aquatic worms.

Head Capsule Deformities. Chironomidae head capsule deformities were observed in all waterways of the CRS, except the LCR-S and Indian Creek (Table 10). Among these waterways, the Calumet River had the highest incidence of deformities (3.1 percent) in the HD samples, while Thorn Creek had the highest incidence of deformities (22.5 percent) in PP samples. Overall head capsule deformities were observed at a higher rate in PP samples (5.8 percent) than HD samples (1.4 percent).

Fish

Between 2001 and 2012, 44 hours of electrofishing (backpack and boat), and 19 minutes of seining yielded 14,316 fish, with a total catch weight of 4,085.8 kilograms, in the CRS. A total of 45 fish species, including 20 game species, one state threatened species, and four hybrids were collected from stations in the CRS. The majority of fish that were collected in the CRS were collected using electrofishing methods. However, seining at Burnham IC yielded a round goby (*Neogobius melanostomus*) in 2003 and two grass pickerel (*Esox americanus vermiculatus*) in 2011. These species were not collected during backpack electrofishing. Seine data are included in the species richness and relative abundance summaries in the remainder of this report, but are not included in the mean IBI scores or the mean catch per unit effort (CPUE) summaries. Species composition in relation to biomass was calculated, and common carp (*Cyprinus carpio*) was the dominant species throughout most of the CRS.

Index of Biotic Integrity. Most of the individual year IBI scores for stations located in the CRS were in the Fair category (21–40) (data not shown). 130th Street was the only station that had five individual IBI scores that were categorized as Good (2005, 2007, 2008, 2010, and 2012). Wentworth Avenue was categorized as Poor in 2007, and this was the only time a calculated IBI score was below 21 in the CRS between 2001 and 2012. It should be noted that no fish were collected during two of the three sampling events at Burnham GCR, so an IBI score was not calculated. Therefore, an average IBI score could not be calculated for the Burnham GCR station, but the individual metrics were averaged using zeros for the sampling events where no fish were collected.

TABLE 10: NUMBER AND PERCENTAGE OF HEAD CAPSULE DEFORMITIES OF CHIRONOMIDAE COLLECTED IN HESTER DENDY AND PETITE PONAR SAMPLES FROM CALUMET RIVER SYSTEM WATERWAYS

Waterway[1]	Hester Dendy			Petite Ponar		
	Total Examined	Total Deformed	Percent Deformed	Total Examined	Total Deformed	Percent Deformed
Calumet River	32	1	3.1	143	1	0.7
Little Calumet River (North)	988	21	2.1	505	17	3.4
Calumet-Sag Channel	1,545	15	1.0	827	44	5.3
Thorn Creek	150	3	2.0	138	31	22.5
Grand Calumet River	191	2	1.0	0	0	0.0
Total	2,906	42	1.4	1,613	93	5.8

[1]Chironomidae not collected in the Little Calumet River (South) or Indian Creek.

The mean IBI score for each station and the mean values of fish metrics that were used to calculate Karr's IBI scores are displayed in Table 11. The lowest mean IBI scores (25) were generated at the Wentworth Avenue, Ashland LCR-S, and Route 83 stations. The 130th Street station had the highest mean IBI score (38). One johnny darter (*Etheostoma nigrum*) was collected at Joe Orr in 2011. This was the only darter species observed in the CRS. Sampling stations on the Calumet River had an average of three intolerant species, but the majority of the stations in the CRS had one or fewer.

Figure 7 shows mean IBI scores for each waterway in the CRS. The highest mean IBI (37) was in the CR and the lowest mean IBI (26) was in the GCR, but the LCR-N and Indian Creek were not far behind with 35 and 34, respectively. Of the stations that had multiple years of fish collection, the LCR-S, CSC, and Thorn Creek all had mean IBI scores of 27.

Species Richness. Fish species richness varied from year to year at most stations. Fish collection at Halsted Street (Station No. 16) yielded the highest species richness in the CRS, with 35 species (Figure 8). Halsted Street also had the highest number of game species (17). The 130th Street (Station No. 55) had the second highest richness with 32 fish species, 12 of which were game species. Burnham Avenue GCR (Station Number 86) had the lowest species richness, with five fish species. The highest number of fish species collected from a single sampling event was 22, at Halsted Street in 2006 (Figure 9).

Fish Abundance. Figure 10 shows the mean CPUE for each waterway in the CRS. The highest mean CPUE in the CRS was at Indian Creek (683 fish per hour). The LCR-N had the highest number of fish per hour (506) of the deep draft sampling stations in the CRS. The GCR had the lowest CPUE (23 fish per hour).

Appendix D displays the relative abundance of fish species in all of the waterways of the CRS except the GCR. It should be noted that data from the GCR in Table D-1 only represents one sampling event where fish were able to be collected. The most dominant species for most of the waterways in the CRS was gizzard shad (*Dorosoma cepedianum*). The relative abundance of gizzard shad increased at sampling stations as the distance from Lake Michigan increased, at stations where boat electrofishing methods were used. Largemouth bass (*Micropterus salmoides*) was the most abundant game fish species in deep draft waterways, and green sunfish (*Lepomis cyanellus*) was the most abundant game fish species at wadeable stations in the CRS. The abundance of game species decreased as the distance from Lake Michigan increased at stations where boat electrofishing methods were used.

The Calumet River had the highest abundance of carnivorous fish species, which included smallmouth bass (*Micropterus dolomieu*), largemouth bass, and rock bass (*Ambloplites rupestris*), representing 27 percent of the fish collected (Table D-1). Rock bass and smallmouth bass are considered intolerant species (Smith, 1979), and were collected frequently in the Calumet River, accounting for 16 percent of the fish collection. Overall, the Calumet River had the highest abundance of game fish among the deep draft waterways, with 35 percent of the fish collected being game species.

Brown bullhead (*Ameiurus nebulosus*), central mudminnow (*Umbra limi*), skipjack herring (*Alosa chrysochloris*), spottail shiner (*Notropis hudsonius*), and white bass (*Morone chrysops*) were only collected in the LCR-N (Table D-1). Black buffalo (*Ictiobus niger*),

TABLE 11: SUMMARY OF FISH INDEX OF BIOTIC METRICS FOR STATIONS IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2012

Mean of Fish IBI[a] Metrics	Calumet River		Little Calumet River North		Calumet-Sag Channel			Little Calumet River South		Thorn Creek		Grand Calumet River	Indian Creek
	130th Street	Ewing Avenue	Indiana Avenue	Halsted Street	Ashland Avenue	Cicero Avenue	Route 83	Ashland Avenue	Wentworth Avenue	170th Street	Joe Orr Road	Burnham Avenue	Burnham Avenue
# of Fish Species	15	5	17	17	11	11	7	9	5	6	4	2	7
# of Sucker Species	2	0	1	1	0	0	0	0	1	1	0	0	0
# of Sunfish Species	4	1	4	4	3	2	1	3	1	1	1	1	3
# of Darter Species	0	0	0	0	0	0	0	0	0	0	1	0	0
# of Intolerant Species	3	3	1	1	0	0	0	1	0	0	0	0	2
Proportion of Green Sunfish	0.9	0.0	2.6	1.2	6.1	4.8	3.9	5.4	4.0	17.8	39.4	0.0	15.6
Proportion of Hybrids	0.0	0.0	0.1	0.0	0.4	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0
Proportion of Disease	1.6	1.6	3.6	5.6	7.0	3.6	2.0	2.8	0.0	5.6	3.3	7.4	2.2
Proportion of Omnivores	54.7	3.1	64.5	53.5	67.5	72.1	88.2	85.8	73.4	33.5	0.8	27.8	35.4
Proportion of Insectivores	9.3	0.6	6.3	5.9	0.3	8.0	2.3	1.2	2.1	0.0	20.7	0.0	0.1
Proportion of Carnivores	24.4	85.7	14.2	15.2	11.8	11.2	2.8	2.8	1.3	11.9	0.0	1.9	6.2
Total Abundance	311	87	427	374	109	215	126	90	14	9	21	6	196
Fish per Hour (CPUE[b])	396	118	565	491	154	313	245	205	104	60	58	23	683
IBI[a] Score	38	34	35	35	25	28	25	29	25	27	28	26[c]	34

[a]Index of Biotic Integrity.
[b]Catch per unit effort.
[c]Index of Biotic Integrity score for 2007 (no other scores could be calculated).

FIGURE 7: MEAN FISH INDEX OF BIOTIC INTEGRITY SCORES OF WATERWAYS IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2012

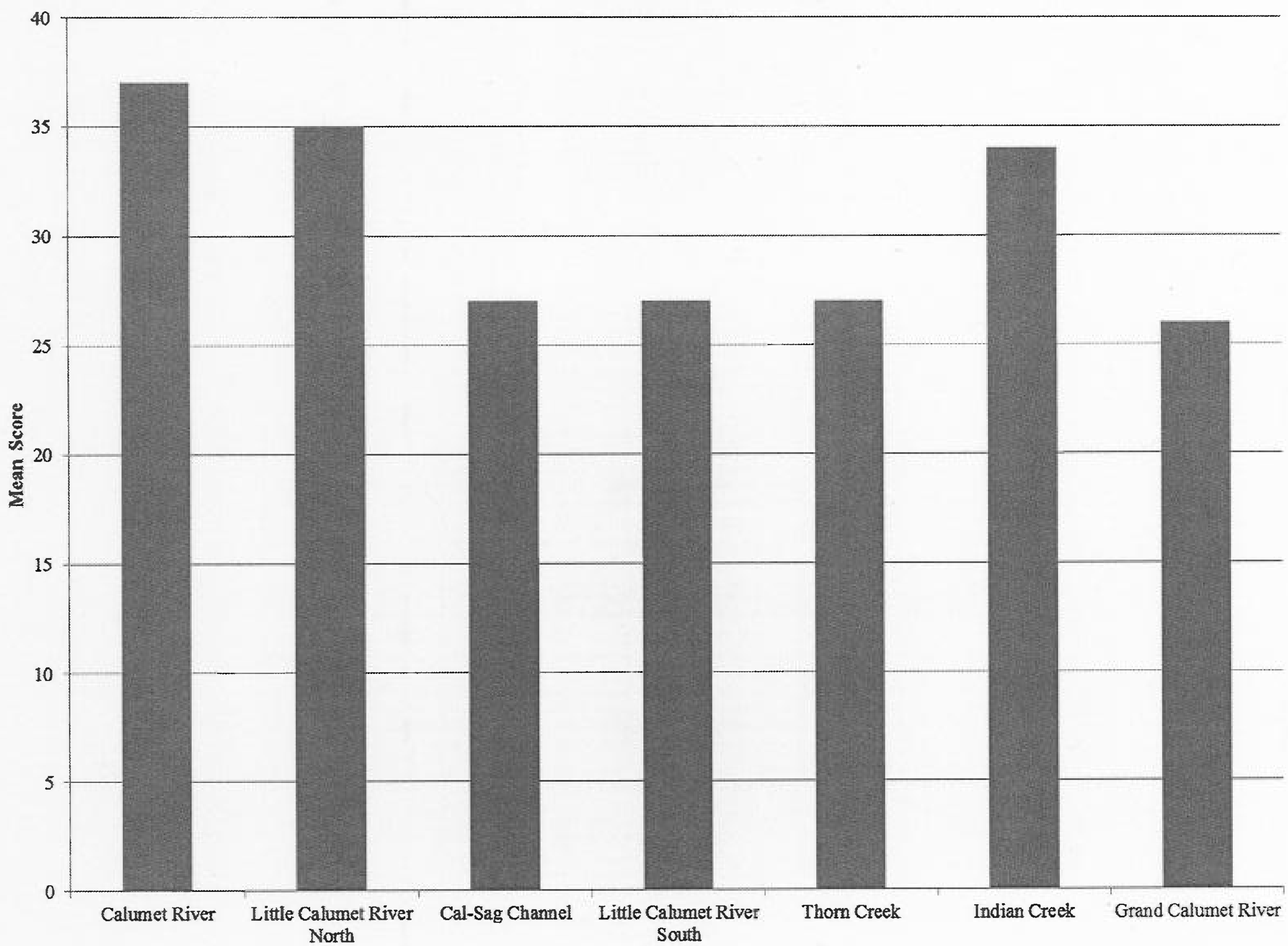


FIGURE 8: NUMBER OF FISH SPECIES COLLECTED AT STATIONS IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2012

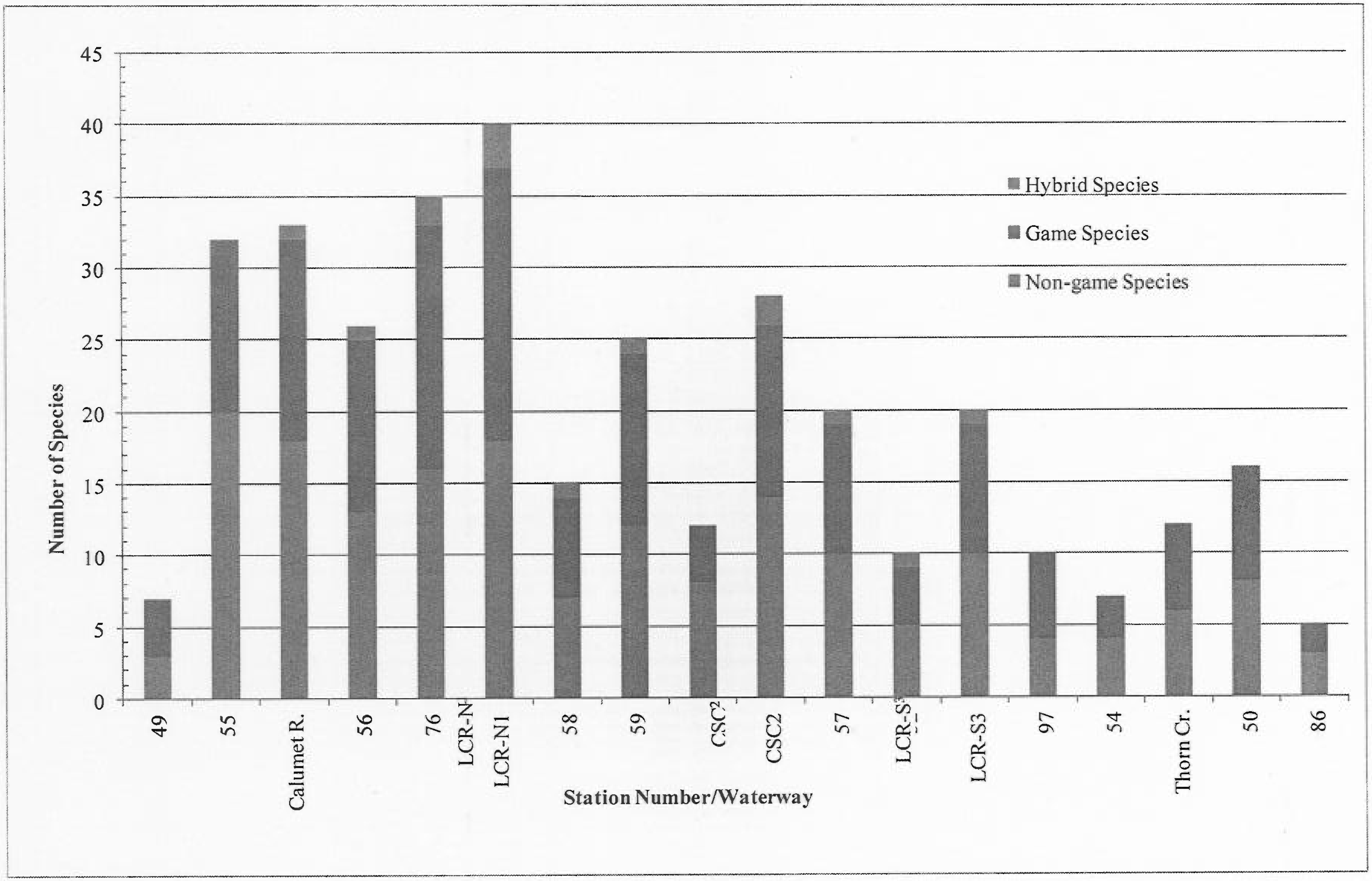


FIGURE 9: NUMBER OF FISH SPECIES COLLECTED AT HALSTED STREET ON THE LITTLE CALUMET RIVER NORTH BETWEEN 2001 AND 2012

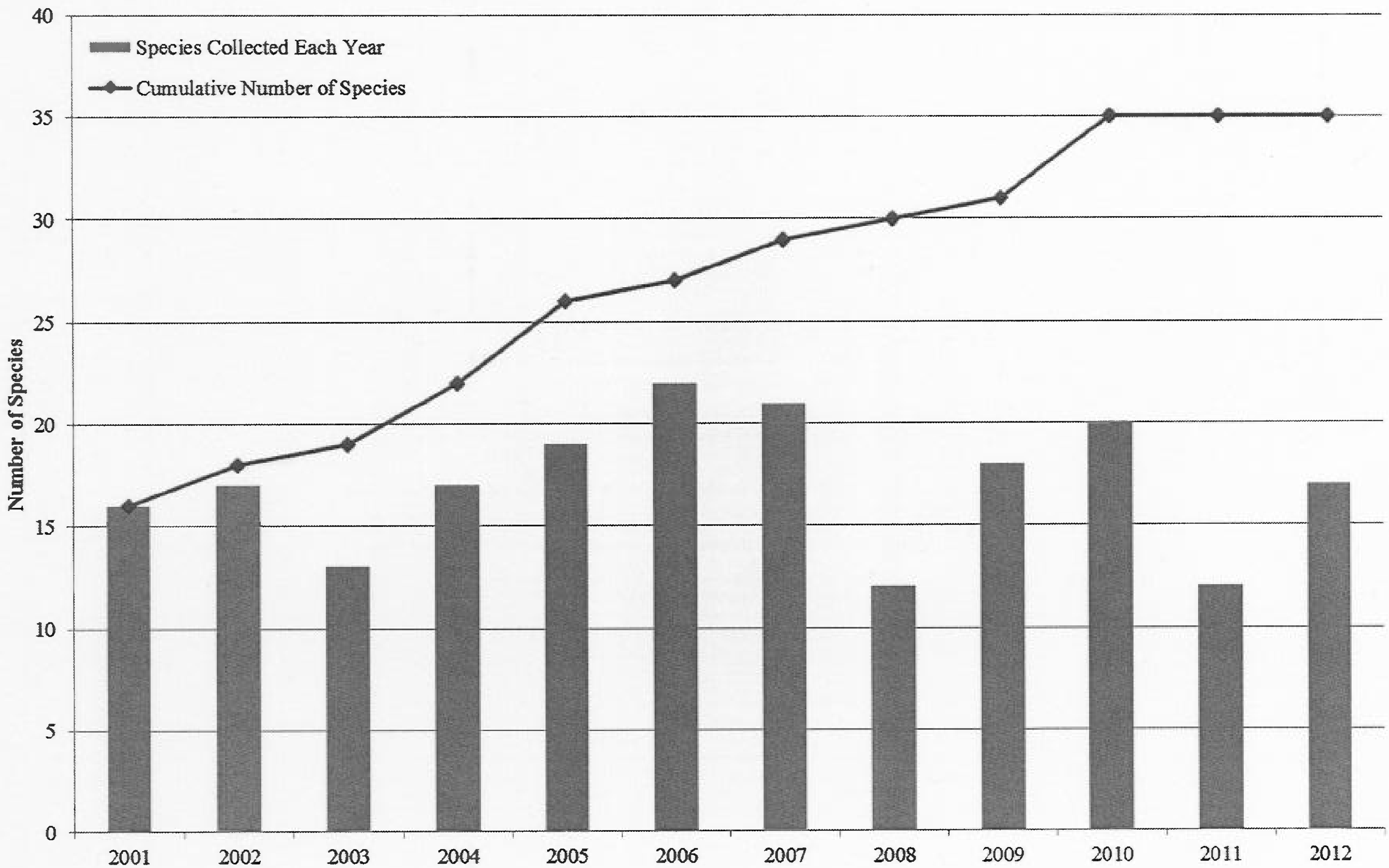
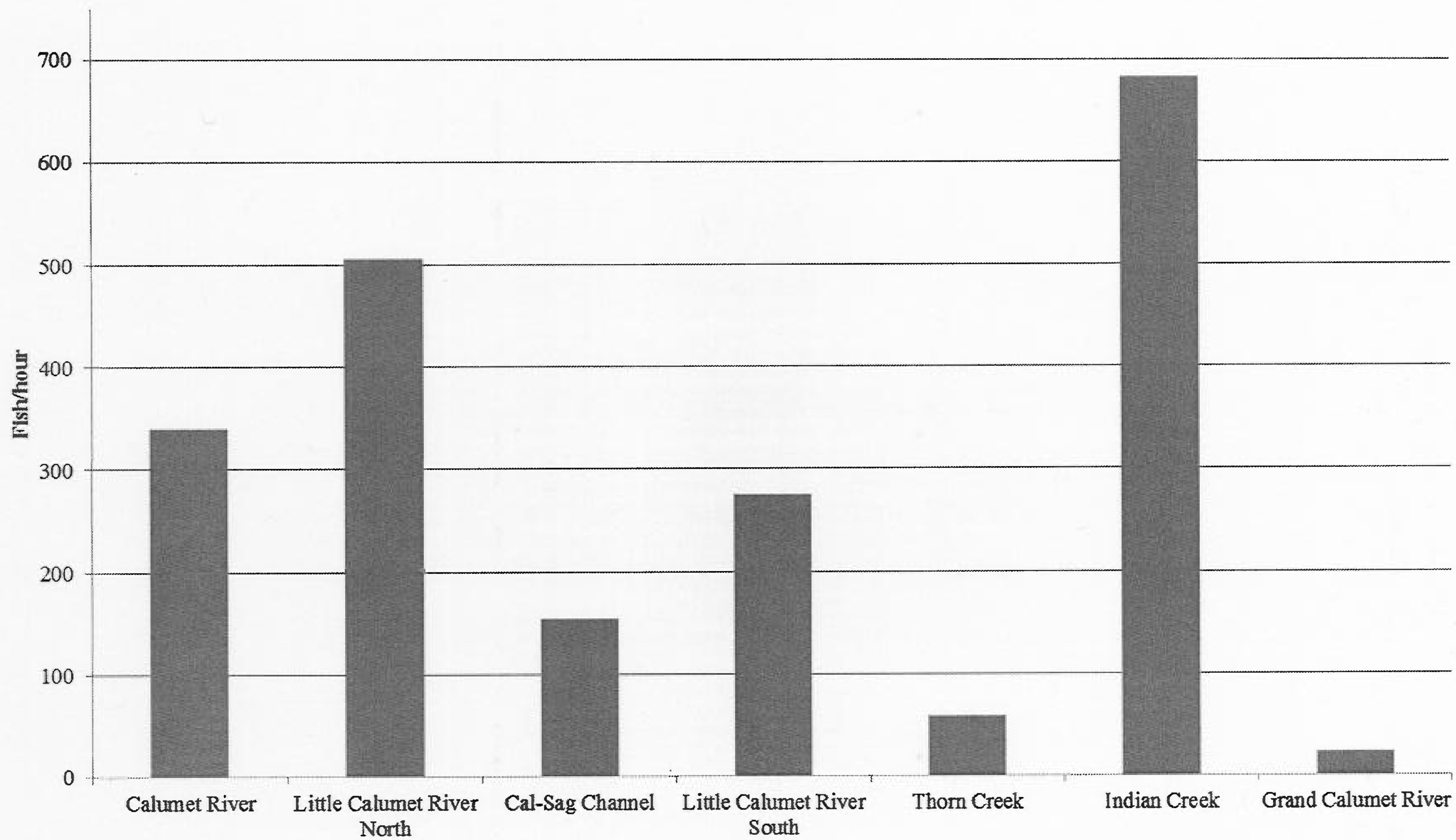


FIGURE 10: MEAN CATCH PER UNIT EFFORT OF FISH IN WATERWAYS OF THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2012



smallmouth buffalo (*Ictiobus bubalus*), chinook salmon (*Oncorhynchus tshawytscha*), northern pike (*Esox lucius*), and yellow perch (*Perca flavescens*) were only collected in the Calumet River and LCR-N.

Water Quality

Water Quality Trends. The summary of statistical analyses for TSS, TAN, and DO are presented in Appendix E. There was either no significant difference among yearly data or no trend identified for TSS between 2001 and 2012 at any AWQM stations, except 130th Street and Indiana Avenue, where the Mann-Kendall analysis demonstrated a negative TSS trend. TAN concentrations tended to decrease over the study period at Ewing Avenue and 170th Street, but increase at Burnham GCR and Cicero Avenue. There were otherwise no significant trends identified for TAN at other CRS locations. Of all the CDOM stations, only 104th Street on the CSC demonstrated a decreasing DO trend between 2001 and 2010 (this monitoring station was discontinued in October 2010). The other stations exhibited either no significant difference among years or no DO trend.

DISCUSSION

Deep Draft Waterways

Fish metrics including IBI scores, CPUE, and species richness and composition were variable from year to year throughout the CRS and showed no trend between 2001 and 2012. Electrofishing efficiency varies depending on depth, weather, water temperature, conductivity, turbidity, and other factors, so fish data can be quite variable between collections. For instance, the total species richness between 2001 and 2012 was 35 at Halsted Street (Figure 8), yet the number of species collected in a single year ranged from 12 to 22 (Figure 6). Some species may also be underrepresented because of particular fish behavior, habitat preference, and the limitations of the electrofishing method. With consistent, continued sampling over time, however, the fish data collected are expected to reflect the fish species present in a given system and provide a good indicator of water quality improvements or other changes in the long-term.

Lack of darter, intolerant, sucker, and insectivore species, and elevated proportions of diseased fish and omnivore species, were some of the main factors resulting in IBI scores categorized as Fair throughout the CRS. Darter species were lacking at all stations in the CRS, but many darter species do not have swim bladders (Page, 1983). When darters are stunned by electrical current they can be difficult to net among large rocks because they do not float. This could be a reason why darters are not collected at stations where only electrofishing methods were used in the CRS. Another reason may be the establishment of the invasive round goby, which are increasingly prevalent in the CRS. Round gobies are a benthic fish species like darters, and have been known to competitively exclude other benthic species (Willink, 2009). A Fair IBI score indicates that some amount of degradation or disturbance has occurred, which would be expected since all of the deep draft waterways in the CRS are manmade or man-altered and provide drainage for urban areas. Variability in metrics caused IBI scores to be variable from year to year and no significant temporal improvements or decreases in IBI scores were evident.

A best case scenario range of scores for deep draft stations using Karr's IBI would probably be 35 to 44, if habitat improvements were strategically made throughout the system, because the highest IBI score in the CRS was 44 (130^{th} Street), and the mean IBI score at the two stations with the highest CAWSHI scores was 35 (Halsted Street and Indiana Avenue) (Table 11). However, using an IBI that was developed for small streams to assess the biological integrity and potential of a large mostly manmade and man altered waterway is not recommended. Development of a fish IBI that is specifically designed and calibrated for the CAWS is needed to accurately assess the biological integrity and potential. The District could work with other groups that also have CAWS fish data, or a vested interest in the CAWS, to help develop a CAWS IBI with the best applicable data available. A CAWS specific IBI could also be used to assess aquatic life use attainment and evaluate the successes or failures of habitat restoration or improvement projects. The IEPA currently does not use IBI thresholds to assess aquatic life use in any deep draft waterways, because appropriate indices do not exist in Illinois. According to the current small streams IBI used by IEPA (which is a different than the IBI used for the AWQMP) a score of 41 or greater indicates full support of aquatic life uses (IEPA, 2014). An area or reach with an IBI score over 41 and less than 51 classifies that waterway segment as a highly valued resource (IEPA, 2014).

Habitat in the deep draft portion of the CRS was a limiting factor for IBI scores. Halsted Street, Indiana Avenue, and Cicero Avenue had the highest CAWSHI scores and also had the highest mean IBI scores (Tables 5 and 11), of the stations where habitat quality was also assessed. This was not surprising considering that the metrics used to calculate CAWSHI were derived mainly from AWQMP fish data (LimnoTech, 2010). Karr's IBI uses different fish metrics than the fish metrics chosen by LimnoTech to help define the relationship between fish and physical habitat in the CAWS. However, Karr's IBI includes six metrics that are the same or similar to metrics chosen by LimnoTech: CPUE, proportion of disease, amount of intolerant species, number sunfish species and proportions of insectivores and carnivores. Of the aforementioned fish metrics, mean CPUE and mean proportion of insectivores were higher at Halsted Street, Indiana Avenue, and Cicero Avenue, probably due in part to the lack of riprap banks, lack of manmade structures, fewer vertical wall banks, absence of sediments with organic sludge composition, and the presence of off- channel bays. Halsted Street and Indiana Avenue also had the highest mean species richness, which was reflected in their IBI scores (Figure 8 and Table 11).Proximity of sampling stations to lake habitats (Lake Michigan or Lake Calumet) also heavily impacted species richness, since the lakes provide a source of fish that move into and through the CRS. For example, banded killifish (*Fundulus diaphanus*), rock bass, grass carp (*Ctenopharyngodon idella*), and quillback (*Carpiodes cyprinus*) were all unique to the Calumet River (Table D-1), which flows east and south from Lake Michigan. Quillback prefer clear water as well as stable substrate (Smith, 1979), while grass carp, banded killifish, and rock bass require vegetated habitat, which is most prevalent in certain reaches of the Calumet River, particularly directly upstream of the O'Brien Lock and Dam. The banded killifish was the only state threatened fish species collected in the CRS. Only one grass carp, an invasive species that feeds on vegetation, was collected between 2001 and 2012.

The Calumet River also had the highest mean IBI in the CRS due to the relatively high numbers of sucker, intolerant, and carnivore species (Table 11). Ewing Avenue, the closest sampling station to Lake Michigan, was the only station where the relative abundance was dominated by carnivorous fish species, with a mean proportion of over 85 percent. However, this station only yielded a total of seven species (Figure 8), as the habitat in the sampling area is dominated by vertical walls and deep water. There were only a few shallow areas with vegetation and other types of instream habitat at each of the other deep draft sampling locations, partially accounting for the higher fish yields. In addition, boat electrofishing loses efficiency as water depth increases, and is most efficient in shallow areas where the electrical current can reach throughout the water column (Reynolds, 1996).

The influence of Lake Michigan was still evident in the LCR-N, where the highest numbers of fish species were collected. These included five fish species that most likely originated from the lake, which were also collected in the Calumet River. The fish species unique to the LCR-N are also likely to exist in the Calumet River, but were not collected between 2001 and 2012. The fish species collected only in the LCR-N were the brown bullhead, white bass, spottail shiner, central mudminnow, and skipjack herring (Table D-1). Brown bullhead and white bass prefer clear water and firm substrate (Smith, 1979). Spottail shiners are prevalent in the shallows of Lake Michigan (Smith, 1979), and had been collected by the District in the LCR-N prior to 2001. The central mudminnow requires mud substrates and vegetation (Simon, 2011). Both substrates were present in reaches of the LCR-N, and central mudminnows have been collected prior to 2001 in the CSC by the District. Skipjack herring were introduced into Lake Michigan (Simon, 2011) and were not collected in the CRS by the District prior to 2001.

Game fish species richness and abundance were lower in the CSC than the Calumet River and the LCR-N. The most abundant sunfish species in the CSC was green sunfish (Table D-1), which is considered pollution tolerant and indicates disturbance or degradation. Eighteen percent of the fishes collected in the CSC were golden shiners (*Notemigonus crysoleucas*), primarily as a result of one sampling event in 2012. Western mosquitofish (*Gambusia affinis*) was the only fish species that was unique to the CSC. The western mosquitofish is associated with vegetation (Simon, 2011) and shallow slow moving water (Smith, 1979), and has been previously collected in the CRS by the District (Dennison et al., 1998).

The Calumet River was the most speciose waterway within the CRS with respect to benthic invertebrates (70 total taxa and five EPT taxa), followed closely by the LCR-N with 67 total and five EPT taxa. Taxa richness was not much reduced in the CSC from the other deep draft waterways (66 and four species for total and EPT taxa, respectively), despite the generally declining sediment quality moving downstream in the deep draft portion of the CRS. This may be because the HD samplers provide artificial substrates in the water column for colonization mainly by attached invertebrate forms, so they would have had less exposure to the contaminated sediment (Cairns, 1982). Almost all of the EPT organisms that were found in the CRS were collected via HD sampler.

Taxa richness was generally higher in HD than Ponar samples, except during some years in the Calumet River where zebra and quagga mussels heavily colonized the artificial substrates. In addition, overall head capsule deformities were observed at a higher rate in Ponar samples (5.8 percent) than HD samples (1.4 percent). HBI scores were very similar in Ponar samples throughout the deep draft waterways, likely because the samples are dominated by Oligochaete worms and other tolerant taxa that can live in the fine silty sediment that is ubiquitous throughout the CRS. While the HBI scores were slightly lower (better) in the HD than the Ponar samples, all of the HBI scores were considered Poor or Fairly Poor.

Organisms from the phylum Annelida dominated the LCR-N and CSC stations, comprising 68.4 and 83.1 percent of the samples. The abundance of tolerant aquatic worms is an indicator of a polluted or impaired waterway. Bivalvia density was extremely high in the Calumet River and then decreased with distance from Lake Michigan. Between 2001 and 2006, the class of Bivalvia was mostly represented by the invasive zebra mussel. However, between 2007 and 2010 there was an introduction and shift toward dominance of the invasive quagga mussel in the CRS.

The shift from zebra to quagga mussel is reflective of their relative abundance in the Great Lakes. Zebra mussels were first discovered in 1988 in Lake St. Clair, located between Lake Huron and Lake Erie (Nalepa et al. 2009). By 1990, they had spread into all five of the Great Lakes, and by 1991 they moved into the Illinois and Hudson Rivers. Since then, zebra mussels have spread into many large navigable rivers in the eastern United States, as well as small lakes within the states surrounding the Great Lakes. The quagga mussel was first discovered in 1988 in Port Colborne, Lake Erie. It then slowly moved west, and was not discovered in Lake Superior until 2005. The first sighting of quagga mussels outside the Great Lakes basin was made in the Mississippi River between St. Louis, Missouri and Alton, Illinois in

1995. By 2005, the quagga mussel displaced the Zebra mussel as the dominant species in Lake Michigan, comprising 97.7 percent of the total population.

In the deep draft portion of the CRS, sediment contamination and toxicity were relatively low in the Calumet River compared to the LCR-N and CSC. These findings agree with the IEPA's 2014 305b report, in which contaminated sediments are listed as one cause of impairment in the CSC and LCR-N. The poorest sediment quality based on SQGs and toxicity test survival was detected at the stations farthest downstream of Lake Michigan in the CRS, Cicero Avenue and Route 83. These stations were the only ones that showed 100 percent of the samples having survival toxicity during the *Chironomus tentans* 10-day toxicity tests. They also had the highest incidence of COC greater than the PEC, while showing <2 percent of the COC below the TEC. This observed toxicity is likely contributing to the domination of pollution tolerant aquatic worms at these stations, as well as the highest incidence of head capsule deformities in *Chironimidae*.

Habitat Improvement Potential. A report on the habitat improvement potential of the CAWS (LimnoTech, 2010) evaluated the potential for physical habitat enhancement in each of the CAWS reaches, the cost, and the likelihood that the enhancements would improve fisheries condition in the CAWS. Recognizing that the CAWS is irreversibly altered due to substantial hydrological modifications, channelization, watershed urbanization and substrate alteration and contamination, the study did not attempt to evaluate strategies for restoration to native or natural conditions. Rather, the study evaluated improvements that could potentially optimize habitat in the reaches with the best CAWSHI scores, which have the best habitat in the CAWS, and possibly improve physical habitat quality in other reaches to higher levels. The North Shore Channel (NSC) north of the O'Brien WRP, with a CAWSHI score of 75, represents the optimum achievable habitat for this system. Recommendations include removal of vertical wall banks and installation of the following: vegetated revetment, chamber revetment, sunken structure, floating vegetation, artificial seaweed and linear shallows. A linear shallow is a method of creating shallow habitat intermittently connected and parallel to a vertical wall canal while maintaining the original functionality of the canal (LimnoTech, 2010). Removal of structures that prohibit biota from using lateral habitats like migration corridors, lakes and sloughs is a common technique used to rehabilitate floodplain connectivity (Roni, et al., 2008). Currently, Tinley Creek flows north into the CSC but is separated by a large concrete structure that does not allow fish to swim in to Tinley Creek. The CRS could benefit from establishing two-way connectivity with Tinley Creek. The CRS would also benefit greatly by establishing connectivity with two nearby lakes. The Saganashkee Slough, and Lake Katherine are relatively close to the CSC but are at a higher elevation than the canal, so establishing a two-way connection with both lakes might be difficult. Currently, three other tributaries connect directly to the CRS. Mill, Stony, and Midlothian Creeks all connect directly to the CRS. Tributaries connecting directly to waterways in the CRS could be evaluated for habitat quality, and the fish communities could be assessed to determine if main channel fish are frequently using them for refuge or recruitment. It might be more practical and cost effective to construct habitat improvements in a relatively small portion of a tributary than in the deep draft waterway.

Comparison to Historical Data. The total number of fish species collected in the LCR-N during 2001 to 2012 was much higher than the total number of species that were collected by the District from 1974 to 1996. Sampling between 2001 and 2012 in the LCR-N yielded 37 species, excluding hybrids (Table D-1), while only 27 species were collected in the LCR-N between 1974 and 1996, excluding hybrids and fish collected at SEPA stations (Dennison et al., 1998). The District collected fish at Halsted Street and the I-94 bridge stations between 1974 and 1996. However, the increase in the total number of species was not solely due to the difference between the I-94 bridge and Indiana Avenue stations, because the number of species over time increased by the same number at Halsted Street. Prior to 2001, the sampling in the LCR-N yielded the second highest mean CPUE in the CRS (Dennison et al., 1998). The mean CPUE of the LCR-N after 2001 was three times the mean CPUE of the 1990s.

The increase in the number of fish species and CPUE can be due partly to the cessation of chlorine disinfection at the Calumet WRP in 1984, because residual chlorine from effluent discharge is known to be toxic to aquatic life. Aquatic vegetation may have also proliferated in the LCR-N following the cessation of disinfection, which would have increased fish habitat. Overall, the improvements in CRS water quality likely influenced the increased number of fish species and CPUE. Another possible reason for the difference is the use of different electrofishers. Between 1974 and 1996, the District primarily used a boat mounted alternating current electrofisher (Dennison et al., 1998), while pulsed direct current electrofishers were used between 2001 and 2012. McClelland et al. (2011) found that pulsed direct current CPUE data were significantly higher than alternating current CPUE data at the same sites. There have been many other studies that have compared the efficiencies of pulsed direct current and alternating current electrofishers with some mixed results, but overall the consensus is that pulsed direct current yields higher catch rates than alternating current electrofishers.

The total number of species collected in the CSC between 2001 and 2012 (26) was very similar to the number collected between 1974 and 1996 (25), when hybrid species and fish species collected at SEPA stations are excluded. However, mean CPUE was significantly higher between 2001 and 2012 (155 fish/hour) than during the 1990's (64 fish/hour). This could be a result of many factors, but the change in type of electrofishers could have contributed to this difference.

The total number of species collected in the Calumet River between 2001 and 2012 (32) was actually less than the number collected between 1974 and 1996 (40), excluding hybrids and fish collected at SEPA 1 (Dennison et al., 1998). More species may have been collected before 2001 in the Calumet River because fish were collected at 130th Street and not Ewing Avenue. The average number of species collected at Ewing Avenue was five, as opposed to 15 at 130th Street (Table 11) due to a lack of fish habitat at Ewing Avenue. Prior to 2001, fish were collected in the Calumet River at 130th Street, and a second site of similar habitat closer to the O'Brien Lock and Dam, where 36 species were collected (Dennison et al., 1998). This site had similar habitat to the 130th Street Station. Differences in the number of species could also be a result of collection frequency, because prior to 2001 fish were collected as much as four times per year at each station (Dennison et al., 1998).

During 1990 and 1991, the District conducted an evaluation of the distribution of benthic invertebrates in the CAWS. There were two stations on the Calumet River, two stations on the LCR-N, and three stations on the CSC. This evaluation identified 78 total taxa and four EPT taxa collected in the Calumet River, 37 total taxa and 0 EPT taxa in the LCR-N, and 31 total taxa and one EPT taxa in the CSC (Polls et al., 1991, 1992). The evaluation also showed a community composition heavily dominated by Annelida: 71.6 percent in the Calumet River, 68.9 percent in the LCR-N, and 92.0 percent in the CSC (Polls et al., 1991, 1992). The highly silted and polluted sediment that is found throughout the CRS is a major factor contributing to this composition.

Though there were fewer benthic taxa collected in the Calumet River from 2001–2010 than 1990–1991, there were significantly more taxa collected in the LCR and the CSC from 2001–2010. The increased number of taxa collected in the LCR-N and CSC may be attributed to the use of HD samplers, which are most influenced by water quality. In 1990–1991 only Ponar grab samples were used for benthic macroinvertebrate collection. The fewer number of taxa collected from 2001–2010 in the Calumet River appear to be a result of the dominance of zebra and quagga mussels following the introduction and subsequent spread of these invasive species. Zebra mussels were introduced to the Great Lakes in 1986 (Herbert et al., 1989, Mackie et al., 1989) and quagga mussels are estimated to have been introduced in 1989 (May and Marsden, 1992).

The District conducted sediment sampling and analysis in parts of the CRS in 1992 and 1993, as part of an effort to establish baseline information on sediment quality for future comparison. Summary results for sediment samples collected within the Calumet River were reported in a separate report for the LCR-N and CSC (MWRD, 1993) and for the GCR (MWRD, 1994). The sediment samples were analyzed for selected inorganic and organic constituents. The deep draft waterways sampled in 1992 were compared to the mean results for the samples collected in 2003 and 2007. The sediment results for TS and TVS were similar, and the NH_3-N and TCN were much lower in 2003 and 2007. The TP and phenols results were similar in the Calumet River, but considerably lower in 2003 and 2007 for the LCR-N and CSC. The trace metals were much lower in 2003 and 2007 compared to 1992, with only a few exceptions. The most notable was an increase in manganese found in the LCR-N, which might be attributed to an isolated "hot spot" in the sediment, or could reflect a new industrial source input that was not there in 1992. Overall, this data comparison shows a marked improvement in sediment quality for these deep draft waterways in the CRS, which could explain some of the biological improvements observed from 2001 through 2012, compared to the 1990s, such as increases in the number of benthic taxa in the LCR-N and CSC.

Wadeable Waterways

Overall, the wadeable stations in the CRS were limited by a number of the same metrics that limited the deep draft stations, resulting in IBI scores in the Fair range between 2001 and 2012. Like the deep draft stations, IBI scores at wadeable stations varied from year to year with no significant changes over time. In general, there were very few sucker, sunfish, darter, and intolerant species. Thorn Creek was the only waterway where a darter species (johnny darter) was collected. Between 2001 and 2012, only one johnny darter was collected in the CRS; it was collected in Thorn Creek in 2011. The johnny darter is the most common darter in the Chicago region and it is not particularly sensitive to environmental degradation (Willink, 2009). The invasive round goby was collected from most of the wadeable stations, which suggests the possibility of competitive exclusion of native darter species, as well as degradation of ideal habitat for darter species. The average proportion of green sunfish was highest in Thorn Creek, and elevated in some of the wadeable waterways. High proportions of green sunfish suggest that some degradation or disturbances of the stream have occurred, which would be expected considering Thorn Creek and the other wadeable waterways in the CRS are man-altered and provide drainage for urban areas. With habitat improvements and restoration, IBI scores in the wadeable portion of the CRS could potentially improve to ≥40, which would indicate aquatic life use attainment for fish (IEPA, 2014). Like the deep draft waterway sampling stations, CPUE and species richness varied at wadeable stations between 2001 and 2012. Burnham Avenue GCR had the lowest abundance of fish and CPUE, because fish were only collected during one of three sampling events (Figure 10). Ashland LCR-S and Burnham IC had the highest mean CPUE and species richness of the wadeable waterways in the CRS. This could be partially explained by the QHEI scores, as Ashland LCR-S and Burnham IC had the second- and third-highest QHEI scores, respectively. Also, Joe Orr had the highest QHEI score (Table 4) and was the only station where a darter species was collected. Burnham IC had the highest CPUE of all the stations in the CRS (683 fish per hour), primarily because the 2011 sampling event yielded 706 bluntnose minnows. Some variation in CPUE was likely due to the different collection methods and sampling ranges.

The presence of game species and their abundance in the wadeable waterways of the CRS was influenced by habitat and adjacent waterways. Burnham IC and Ashland LCR-S had the highest number of game fish species (Figure 8). However, game fish did not comprise a large proportion of the collections from LCR-S or IC (Table D-1). Common carp, gizzard shad, and goldfish accounted for over 75 percent of the fish collected in the LCR-S. The game species that were collected in the LCR-S were also present in the adjacent LCR-N. The collection of northern longear sunfish (*Lepomis peltastes*) at Burnham IC was likely influenced by the proximity to Wolf Lake. This species was unique to Indian Creek and is native to Wolf Lake (Willink, 2009). They do not grow much longer than 100 millimeters (Smith, 1979). The largest northern longear sunfish that was collected from Burnham IC was 105 millimeters and therefore at about the maximum length for the species. The dominance of bluntnose minnows in Indian Creek (Table D-1) was a direct result of the 2011 collection. Bluntnose minnows had not been collected during the two previous collections. The fish community in Thorn Creek was dominated by the game species green sunfish. Green sunfish were considered a game species, but are also considered pollution tolerant and indicate disturbance or degradation. Creek chub (*Semotilus atromaculatus*) was the second most abundant species, and were more abundant in Thorn Creek than in any of the other CRS waterways. The abundance of creek chub in Thorn Creek was to be expected, since they are generally abundant in creeks, especially in low-gradient streams with mud or clay substrates (Smith, 1979).

Thorn Creek was the most speciose waterway within the wadeable portion of the CRS with respect to benthic invertebrates (61 total taxa and seven EPT taxa), followed closely by the LCR-S with 59 total and five EPT taxa. Taxa richness then dropped significantly in IC (34 and four species for total and EPT taxa) and the lowest richness observed in the GCR (26 and 0 species for total and EPT taxa). Sediment quality with respect to chemistry was greatest at Burnham GCR, which was the probable cause of the low taxa richness. As observed for the deep draft waterways, taxa richness was generally higher in HD than Ponar samples. HBI scores were very similar in Ponar samples throughout the wadeable waterways, likely because the samples are dominated by Oligochaete worms and other tolerant taxa that can live in the fine, silty sediment that is ubiquitous throughout the CRS. While HBI scores were slightly lower (better) in the HD than the Ponar samples, all of the HBI scores were considered Fairly Poor to Very Poor. Organisms from the phylum Annelida dominated all the wadeable stations of the CRS. The abundance of these tolerant aquatic worms is an indicator of a polluted or impaired waterway.

As previously mentioned, the wadeable stations with the highest QHEI scores were Joe Orr and Ashland LCR-S. These stations also exhibited the most species richness for both fish and macroinvertebrates. The results of Pearson correlation analysis showed a positive and significant relationship between IBI and QHEI scores, and that reduction in riffle and pool areas associated with channelization were the most significant factors influencing fish assemblage (Laub et al., 2012). Using logistic regression techniques to model the relationship of macroinvertebrate assemblage and habitat structure showed that cross sectional area at bankfull discharge, percent shallow water habitats, percent slow water habitats, and percent fines were the most important habitat variables to macroinvertebrates (Richards et al., 1997). Joe Orr had the least amount of channelization, the most high quality instream cover, and the greatest species richness (fish and macroinvertebrate) among the wadeable sampling stations in the CRS. These findings imply a correlation of biota to habitat, which is in line with the results of the aforementioned studies.

The wadeable portions of the CRS showed relatively less sediment contamination and toxicity compared to the deep draft portions, the one exception being the GCR. Sediment from Burnham GCR frequently showed mean and maximum values that were much higher than all other sites. This location on the GCR receives flow from the state of Indiana, and the past industrial activities in this area are the likely cause of these contaminated sediments. In fact, the USEPA has designated this watershed as an Area of Concern in northeast Indiana. This station showed COC concentrations that were greater than the PEC 75 percent of the time and COC less than the TEC was not observed. This waterway was also the only one with no EPT taxa present. It had the lowest total tax richness, and was dominated by tolerant aquatic worms (>99.9 percent). It is important to note that only one station was monitored on the GCR, and more extensive sampling needs to be done to determine if this site is a hot spot for contaminated sediments or if this represents the characteristic of the wider waterway.

The 2014 IEPA 305b report listed the GCR, LCR-S, and Thorn Creek as impaired for aquatic life, with contaminated sediments as one of the sources of impairment. The results found in this report support this finding. These waterways each exhibited some toxicity based on *Chironomid-tentans* survival and or growth. Comparison of sediment chemistry results to the SQGs suggests that there is potential for sediment toxicity in these waterways. Two of the waterways also showed the potential for metal toxicity based on the SEM/AVS ratio. Joe Orr was the only station that showed no sediment toxicity based on the ten-day *Chironomus tentans* toxicity test. It also was the station with the most COC concentrations less than the TEC and least amount of the COC that were greater than the PEC. This is a good example of how the toxicity testing is consistent with the sediment chemistry results and may indicate that more data from chemical analysis might be effective as an indicator of potential for toxicity. Joe Orr also had the highest percentage of sand and gravel and lowest percentage of silt and clay, suggesting that the substrate type influences the toxicity of sediments.

The Thorn Creek stations displayed the highest percentage of *Chironomidae* head capsule deformities. However, sediment toxicity was low at stations in this waterway. Low sediment toxicity in sediment from Thorn Creek suggests that a possible explanation of for head capsule deformities could be complex.

Habitat Improvement Potential. Stream modifications that could improve habitat for fish and macroinvertebrates in wadeable streams (based on QHEI scores) in the District's service area include (1) installation of boulders and large woody debris; (2) improve riffle-run-pool complexes; and (3) restoration of the floodplain of these flashy urban streams. Restored floodplains have been shown to slow destructive high flows and collect and process nutrients (Roley et al, 2011). The location(s) where habitat improvement would be most beneficial depends on the overall goal of the restoration efforts and the economic constraints.

If habitat improvement goals are to simply improve QHEI and IBI scores, then restoration efforts should focus on extending the habitat at Ashland Avenue, Joe Orr Road, or Burnham IC. If the focus is improving a wadeable waterway that would have the most impact on the CAWS, it will be best to target downstream of Ashland Avenue. Ashland Avenue had the second highest QHEI and mean IBI scores among the wadeable sampling locations, but the mean IBI score was still 6 points less than Halsted Street and Indiana Avenue (Tables 4 and 11). Ashland Avenue would also benefit from some connectivity to other areas with good habitat. Improving habitat downstream of Ashland Avenue could extend that area of good habitat all the way to the CAWS and even provide refuge or a nursery area for fish, thereby increasing species richness and mean IBI scores. Halsted Street is in relatively close proximity to the confluence with the LCR-S and Ashland Avenue, and if improvements were completed both downstream of Halsted Street and Ashland Avenue a relatively large area of good aquatic habitat would be created.

Comparison to Historical Data. District personnel collected fish at wadeable stations on Thorn Creek and the LCR-S in 1983 (Schmeelk et al., 1986). The total number of species found in each waterway were similar to what was found between 2001 and 2012. Comparison of the mean CPUE at locations that were sampled in 2001–2012 to those from 1983 show that the CPUE increased fivefold in the LCR-S, but the increase was due mainly to increases in tolerant species. The mean CPUE for Thorn Creek was somewhat similar for the 1983 collection and the 2001–2012 collection. The relative abundance was also somewhat similar in both waterways, with a few exceptions.

The main differences in relative abundance in the LCR-S were (1) that central mudminnow was the third most abundant species in the LCR-S in 1983, but was not collected in the LCR-S between 2001 and 2012, and (2) common carp were almost four times more prevalent between 2001 and 2012 than they were in 1983. In 1983, fathead minnow (*Pimephales promelas*) was the second most abundant species in Thorn Creek. Between 2001 and 2012, fathead minnows were not collected in Thorn Creek and common carp accounted for 10 percent of the fish that were collected. The explanation for these changes in relative abundance is unclear, because both species are prevalent in the CRS.

The only comparable wadeable waterway where sediment was sampled in 1993 was the GCR. When compared to the 2003 and 2007 mean summary data, there are variable results. The TS and TVS results were similar: the NH_3-N, phenols, and TCN decreased, but the TP increased. The total metals including cadmium, nickel, silver, and zinc decreased, whereas chromium, copper, iron, lead, and manganese increased. Total mercury was similar for both periods. This data comparison for the GCR suggests that contaminants persist in this waterway.

Future Biological Monitoring

Water quality did not change measurably between 2001 and 2012, but water quality in the District service area waterways was significantly improved in the prior 30 years due to various improvements in wastewater treatment and the TARP. The District is currently working on a number of major projects to further enhance water quality and positively impact the Chicago area waterways. Potential improvements resulting from such investments as reduction in phosphorus discharged in WRP effluent, TARP reservoir completion, green infrastructure, habitat improvement, disinfection, and increased operation of existing aeration stations to meet more stringent DO water quality standards can be documented through biomonitoring.

Biological integrity, as represented by fish and invertebrate monitoring, can be an appropriate way to track progress towards the first goal of the Clean Water Act, which is *"Restoration and maintenance of chemical, physical and biological integrity of Nation's waters."* Only fish integrate all of the desired ecosystem evaluation components: water quality, habitat, many trophic levels, sediment quality, food source (macroinvertebrates, algae). The fish IBI can be closely evaluated, metric by metric, to tease out why improvements may be occurring over time. Biological improvements in fish species and health resonate with the public, and represent more accessible and understandable metrics than a compilation of water quality parameters. Fish also provide a good communication/outreach tool on stream health. Biomonitoring is the most reliable and practical tool that can evaluate long term changes, integrating water quality and habitat. In 1994, the USGS found that biological monitoring data and assessments of aquatic communities were needed to determine biological effects of changes in wastewater treatment in the Chicago Area. The USGS also determined that biological analyses can show changes in water quality in ways chemical data cannot, because aquatic organisms integrate the effects of water quality over time (Terrio, 1994).

There are no other agencies performing consistent long-term monitoring events at locations near District WRPs. The Illinois Department of Natural Resources performs fish and macroinvertebrate sampling every five years at limited locations in the local watersheds. The ACOE does occasional sediment quality assessments for specific projects in the CAWS. Standardized annual fish sampling can statistically show changes in species richness, abundance, and integrity, while data generated via quadrennial basin based fish sampling provides information about presence and absence of fish species with little statistical significance. Annual biomonitoring by the District has historically shown that improvements in water quality have a positive impact on aquatic life (Dennison et al., 1998). Continued biomonitoring will enable the District to demonstrate improvements of more recent investments in the future. Biomonitoring could also become a requirement if Illinois adopts Tiered Aquatic Life Use (TALU) standards. The Illinois Association of Wastewater Agencies is pursuing cooperation from IEPA to submit a proposal to the IPCB recommending TALU for the assessment of Illinois waters. A CAWS specific IBI could be used to develop TALU standards. Evaluating the attainment of beneficial uses through TALU is more progressive and equitable than only assessing chemical stressor concentrations. This model encourages the prioritization of limited resources towards actions that may have more significant impacts on biology, like habitat improvement and dam removal.

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APPENDIX A

QUALITATIVE HABITAT EVALUATION INDEX FIELD ASSESSMENT FORM

OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: [ ]

Stream & Location: ______________________ *RM:* ___.__ *Date:* __/__/__

______________________ *Scorers Full Name & Affiliation:* ______________________

River Code: __-___-___ *STORET #:* ______ *Lat./ Long.:* (NAD 83 - decimal °) __.____ /8_.____ Office verified location ☐

1] SUBSTRATE

Check *ONLY* Two substrate *TYPE BOXES*; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]	___	___	☐☐ HARDPAN [4]	___	___
☐☐ BOULDER [9]	___	___	☐☐ DETRITUS [3]	___	___
☐☐ COBBLE [8]	___	___	☐☐ MUCK [2]	___	___
☐☐ GRAVEL [7]	___	___	☐☐ SILT [2]	___	___
☐☐ SAND [6]	___	___	☐☐ ARTIFICIAL [0]	___	___
☐☐ BEDROCK [5]	___	___			

(Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☐ 3 or less [0]

Comments

Check ONE (*Or 2 & average*)

ORIGIN		QUALITY
☐ LIMESTONE [1]	SILT	☐ HEAVY [-2]
☐ TILLS [1]		☐ MODERATE [-1]
☐ WETLANDS [0]		☐ NORMAL [0]
☐ HARDPAN [0]		☐ FREE [1]
☐ SANDSTONE [0]	EMBEDDEDNESS	☐ EXTENSIVE [-2]
☐ RIP/RAP [0]		☐ MODERATE [-1]
☐ LACUSTURINE [0]		☐ NORMAL [0]
☐ SHALE [-1]		☐ NONE [1]
☐ COAL FINES [-2]		

Substrate [ ] Maximum 20

2] INSTREAM COVER

Indicate presence 0 to 3: **0**-Absent; **1**-Very small amounts or if more common of marginal quality; **2**-Moderate amounts, but not of highest quality or in small amounts of highest quality; **3**-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

___ UNDERCUT BANKS [1]
___ OVERHANGING VEGETATION [1]
___ SHALLOWS (IN SLOW WATER) [1]
___ ROOTMATS [1]
___ POOLS > 70cm [2]
___ ROOTWADS [1]
___ BOULDERS [1]
___ OXBOWS, BACKWATERS [1]
___ AQUATIC MACROPHYTES [1]
___ LOGS OR WOODY DEBRIS [1]

AMOUNT

Check ONE (*Or 2 & average*)

☐ EXTENSIVE >75% [11]
☐ MODERATE 25-75% [7]
☐ SPARSE 5-<25% [3]
☐ NEARLY ABSENT <5% [1]

Comments

Cover [ ] Maximum 20

3] CHANNEL MORPHOLOGY

Check ONE in each category (*Or 2 & average*)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☐ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☐ MODERATE [2]
☐ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☐ LOW [1]
☐ NONE [1]	☐ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel [ ] Maximum 20

4] BANK EROSION AND RIPARIAN ZONE

Check **ONE** in each category for *EACH BANK* (*Or 2 per bank & average*)

River right looking downstream

EROSION (L R)	RIPARIAN WIDTH (L R)	FLOOD PLAIN QUALITY (L R)	(L R)
☐☐ NONE / LITTLE [3]	☐☐ WIDE > 50m [4]	☐☐ FOREST, SWAMP [3]	☐☐ CONSERVATION TILLAGE [1]
☐☐ MODERATE [2]	☐☐ MODERATE 10-50m [3]	☐☐ SHRUB OR OLD FIELD [2]	☐☐ URBAN OR INDUSTRIAL [0]
☐☐ HEAVY / SEVERE [1]	☐☐ NARROW 5-10m [2]	☐☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐☐ MINING / CONSTRUCTION [0]
	☐☐ VERY NARROW < 5m [1]	☐☐ FENCED PASTURE [1]	
	☐☐ NONE [0]	☐☐ OPEN PASTURE, ROWCROP [0]	

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian [ ] Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH

Check ONE (*ONLY!*)

☐ > 1m [6]
☐ 0.7-<1m [4]
☐ 0.4-<0.7m [2]
☐ 0.2-<0.4m [1]
☐ < 0.2m [0]

CHANNEL WIDTH

Check ONE (*Or 2 & average*)

☐ POOL WIDTH > RIFFLE WIDTH [2]
☐ POOL WIDTH = RIFFLE WIDTH [1]
☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY

Check ALL that apply

☐ TORRENTIAL [-1]	☐ SLOW [1]
☐ VERY FAST [1]	☐ INTERSTITIAL [-1]
☐ FAST [1]	☐ INTERMITTENT [-2]
☐ MODERATE [1]	☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current [ ] Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (*Or 2 & average*).

☐ NO RIFFLE [metric=0]

RIFFLE DEPTH	RUN DEPTH	RIFFLE / RUN SUBSTRATE	RIFFLE / RUN EMBEDDEDNESS
☐ BEST AREAS > 10cm [2]	☐ MAXIMUM > 50cm [2]	☐ STABLE (e.g., Cobble, Boulder) [2]	☐ NONE [2]
☐ BEST AREAS 5-10cm [1]	☐ MAXIMUM < 50cm [1]	☐ MOD. STABLE (e.g., Large Gravel) [1]	☐ LOW [1]
☐ BEST AREAS < 5cm [metric=0]		☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]	☐ MODERATE [0]
			☐ EXTENSIVE [-1]

Comments

Riffle / Run [ ] Maximum 8

6] GRADIENT (ft/mi)

DRAINAGE AREA (mi²)

☐ VERY LOW - LOW [2-4]
☐ MODERATE [6-10]
☐ HIGH - VERY HIGH [10-6]

%POOL: [ ] %GLIDE: [ ]

%RUN: [ ] %RIFFLE: [ ]

Gradient [ ] Maximum 10

A] SAMPLED REACH

Check ALL that apply

METHOD

- ☐ BOAT
- ☐ WADE
- ☐ L. LINE
- ☐ OTHER

STAGE

1st -sample pass-		2nd
☐	HIGH	☐
☐	UP	☐
☐	NORMAL	☐
☐	LOW	☐
☐	DRY	☐

DISTANCE

- ☐ 0.5 Km
- ☐ 0.2 Km
- ☐ 0.15 Km
- ☐ 0.12 Km
- ☐ OTHER

_____ meters

CLARITY

1st --sample pass--		2nd
☐	< 20 cm	☐
☐	20-<40 cm	☐
☐	40-70 cm	☐
☐	> 70 cm/ CTB	☐
☐	SECCHI DEPTH	☐

pass 1st _________ cm

2nd _________ cm

CANOPY

- ☐ > 85%- OPEN
- ☐ 55%-<85%
- ☐ 30%-<55%
- ☐ 10%-<30%
- ☐ <10%- CLOSED

Comment RE: Reach consistency/ Is reach typical of steam?, *Recreation/* Observed - Inferred, *Other/* Sampling observations, Concerns, Access directions, etc.

___

___

___

___

___

B] AESTHETICS

- ☐ NUISANCE ALGAE
- ☐ INVASIVE MACROPHYTES
- ☐ EXCESS TURBIDITY
- ☐ DISCOLORATION
- ☐ FOAM / SCUM
- ☐ OIL SHEEN
- ☐ TRASH / LITTER
- ☐ NUISANCE ODOR
- ☐ SLUDGE DEPOSITS
- ☐ CSOs/SSOs/OUTFALLS

C] RECREATION

AREA DEPTH

POOL: ☐ >100ft² ☐ >3ft

D] MAINTENANCE

Circle some & *COMMENT*

PUBLIC / PRIVATE / BOTH / NA
ACTIVE / HISTORIC / BOTH / NA
YOUNG-SUCCESSION-OLD
SPRAY / SNAG / REMOVED
MODIFIED / DIPPED OUT / NA
LEVEED / ONE SIDED
RELOCATED / CUTOFFS
MOVING-BEDLOAD-STABLE
ARMOURED / SLUMPS
ISLANDS / SCOURED
IMPOUNDED / DESICCATED
FLOOD CONTROL / DRAINAGE

E] ISSUES

WWTP / CSO / NPDES / INDUSTRY
HARDENED / URBAN / DIRT&GRIME
CONTAMINATED / LANDFILL
BMPs-CONSTRUCTION-SEDIMENT
LOGGING / IRRIGATION / COOLING
BANK / EROSION / SURFACE
FALSE BANK / MANURE / LAGOON
WASH H_20 / TILE / H_20 TABLE
ACID / MINE / QUARRY / FLOW
NATURAL / WETLAND / STAGNANT
PARK / GOLF / LAWN / HOME
ATMOSPHERE / DATA PAUCITY

F] MEASUREMENTS

$\bar{x}$ width
$\bar{x}$ depth
max. depth
$\bar{x}$ bankfull width
bankfull $\bar{x}$ depth
W/D ratio
bankfull max. depth
floodprone x^2 width
entrench. ratio

Legacy Tree:

Stream Drawing:

APPENDIX BI

MEAN AND MAXIMUM VALUES OF GENERAL CHEMISTRY CONSTITUENTS IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

TABLE BI-1: MEAN AND MAXIMUM PERCENT TOTAL SOLIDS AND PERCENT TOTAL VOLATILE SOLIDS IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

Station			% Total Solids				% Total Volatile Solids			
			2003		2007		2003		2007	
No.	Location	Waterway	Mean	Max	Mean	Max	Mean	Max	Mean	Max
52	Wentworth Avenue	Little Calumet River South	45.6*	45.6*	32.5	38.0	10*	10*	12	12
57	Ashland Avenue	Little Calumet River South	27.5*	27.5*	38.0*	38.0*	NA	NA	10*	10*
54	Joe Orr Rd.	Thorn Creek	82.4	88.4	81.0	83.0	NA	NA	2	2
97	170th St.	Thorn Creek	57.7	67.7	62.5	74.0	7	8	5	6
49	Ewing Avenue	Calumet River	62.3*	62.3*	64.0	65.0	5*	5*	5	5
55	130th Street	Calumet River	55.5	65.2	62.5	69.0	NA	NA	3	4
50	Burnham Avenue	Indian Creek	51.9	67.5	65.5	71.0	6	8	3	4
86	Burnham Avenue	Grand Calumet River	35.7	49.6	27.5	28.0	19	19	17	24
56	Indiana Avenue	Little Calumet River North	53.0	61.7	42.0	42.0	6	8	6	6
76	Halsted Street	Little Calumet River North	73.6	78.5	70.0	81.0	11	19	4	5
58	Ashland Avenue	Calumet-Sag Channel	52.1	56.2	55.0	62.0	7	10	9	9
59	Cicero Avenue	Calumet-Sag Channel	53.2	57.5	NA	NA	11	15	NA	NA
43	Route 83	Calumet-Sag Channel	45.4	49.9	49.5	50.0	8	9	8	8

*Only one data point available.
NA = Not available.

TABLE BI-2: MEAN AND MAXIMUM CONCENTRATIONS OF AMMONIA, NITRITE PLUS NITRATE, AND KJELDAHL NITROGEN IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

Station			Ammonia Nitrogen[1]				Nitrite + Nitrate[1]				Kjeldahl Nitrogen[1]			
			2003		2007		2003		2007		2003		2007	
No.	Location	Waterway	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
52	Wentworth Ave.	LCR-S[2]	99*	99*	54	87	0.88*	0.88*	17.00	19.00	3,429*	3,429*	2,708	3,272
57	Ashland Ave.	LCR-S	36*	36*	22*	22*	2.28*	2.28*	11.00*	11.00*	1,948*	1,948*	2,476*	2,476*
54	Joe Orr Rd.	Thorn Cr.	5	6	5	8	4.17	4.90	5.00	6.00	125	150	230	241
97	170th St.	Thorn Cr.	9	13	8	12	0.86	0.89	5.00	7.00	1,234	1,857	836	1,104
49	Ewing Ave.	Calumet R.	25*	25*	20	29	1.24*	1.24*	6.50	7.00	971*	971*	778	809
55	130th St.	Calumet R.	20	27	13	21	1.65	1.79	3.50	5.00	941	1,472	612	891
50	Burnham Ave.	Indian Cr.	10	13	17	19	0.96	1.28	2.50	3.00	952	1,411	331	372
86	Burnham Ave.	GCR[3]	113	142	116	168	6.48	8.48	11.00	16.00	6,000	8,494	5,346	6,034
56	Indiana Ave.	LCR-N[4]	38	64	53	53	1.28	1.41	9.00	10.00	1,344	2,070	1,951	2,026
76	Halsted St.	LCR-N	23	40	16	31	1.46	1.64	4.00	6.00	957	1,664	632	1,095
58	Ashland Ave.	CSC[5]	135	210	37	53	1.75	1.94	6.50	9.00	2,585	3,476	1,739	2,406
59	Cicero Ave.	CSC	44	57	NA	NA	1.10	1.31	NA	NA	1,985	2,371	NA	NA
43	Route 83	CSC	120	175	9	15	0.96	1.04	0.50	1.00	2,753	3,034	2,326	2,339

[1]Concentrations expressed as mg/kg dry weight.
[2]Little Calumet River South.
[3]Grand Calumet River.
[4]Little Calumet River North.
[5]Calumet-Sag Channel.
*Only one data point available.
NA = Not available.

TABLE BI-3: MEAN AND MAXIMUM CONCENTRATIONS OF PHOSPHORUS, PHENOLS, AND CYANIDE IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

		Phosphorus[1]				Phenols[1]				Cyanide[1]			
		2003		2007		2003		2007		2003		2007	
Location	Waterway	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Wentworth Ave.	LCR-S[2]	1,920*	1,920*	1,765	2,355	1.170*	1.170*	0.250	0.300	0.272*	0.272*	0.350	0.400
Ashland Ave.	LCR-S	1,845*	1,845*	1,570*	1,570*	0.316*	0.316*	0.300*	0.300*	0.178*	0.178*	0.200*	0.200*
Joe Orr Rd.	Thorn Cr.	117	118	186	223	0.026	0.033	<0.100	0.100	0.032	0.043	0.100	0.100
170th St.	Thorn Cr.	1,373	1,401	964	1,381	0.105	0.130	0.300	0.400	0.120	0.193	0.150	0.200
Ewing Ave.	Calumet R.	387*	387*	276	286	0.586*	0.586*	0.150	0.200	0.156*	0.156*	0.650	0.800
130th St.	Calumet R.	415	617	267	426	0.333	0.593	0.150	0.200	0.077	0.123	0.300	0.500
Burnham Ave.	Indian Cr.	106	121	53	59	0.074	0.116	0.300	0.300	0.109	0.149	8.800	17.300
Burnham Ave.	GCR[3]	4,889	5,923	5,783	7,062	2.627	3.342	0.600	1.000	0.334	0.412	2.650	3.600
Indiana Ave.	LCR-N[4]	1,310	1,796	1,736	1,750	0.441	0.458	0.400	0.400	0.104	0.120	0.500	0.600
Halsted St.	LCR-N	867	1,173	557	621	0.370	0.414	0.400	0.600	0.084	0.124	<5.850	11.600
Ashland Ave.	CSC[5]	2,408	3,056	2,005	2,647	3.091	3.331	0.100	0.100	0.271	0.317	2.400	2.500
Cicero Ave.	CSC	4,577	5,393	NA	NA	1.897	2.168	NA	NA	0.240	0.282	NA	NA
Route 83	CSC	6,089	7,471	4,549	4,579	2.597	3.136	0.200	0.200	0.177	0.232	3.750	4.700

[1]Concentrations expressed as mg/kg dry weight.
[2]Little Calumet River South.
[3]Grand Calumet River.
[4]Little Calumet River North.
[5]Calumet-Sag Channel.
*Only one data point available.
NA = Not available.

APPENDIX BII

MEAN AND MAXIMUM VALUES OF TRACE METALS IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

TABLE BII-1: MEAN AND MAXIMUM CONCENTRATIONS OF METALS IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

		LCR-S[2]		Thorn Cr.		Calumet R.		Indian Cr.	GCR[3]	LCR-N[4]		Calumet-Sag Channel		
Metal[1]	Year	52	57	54	97	49	55	50	86	56	76	58	59	43
Cadmium	2003 Mean	1.1*	0.6*	<0.3	0.3	0.9*	0.9	0.9*	9.8	1.6	0.9	2.0	3.0	4.9
	Max	1.1*	0.6*	0.5	0.5	0.9*	1.5	0.9*	13.4	1.7	1.4	2.3	4.0	5.8
	2007 Mean	<2.0	2.0*	<2.0	<2.0	<2.0	<2.0	<2.0	7.5	<2.0	2.0	<2.0	NA	5.0
	Max	<2.0	2.0*	<2.0	<2.0	<2.0	<2.0	<2.0	11.0	2.0	2.0	<2.0	NA	6.0
Chromium	2003 Mean	79*	43*	23	37	36*	38	33*	174	54	97	55	65	102
	Max	79*	43*	40	40	36*	61	33*	232	58	143	61	76	114
	2007 Mean	53	22*	20	24	32	27	6	103	47	81	32	NA	94
	Max	64	22*	21	29	40	40	6	149	52	121	33	NA	104
Copper	2003 Mean	58*	35*	19	31	64*	37	26*	430	75	61	69	75	82
	Max	58*	35*	35	35	64*	61	26*	637	96	64	71	79	84
	2007 Mean	54	38*	24	23	43	23	5	254	92	45	45	NA	78
	Max	61	38*	32	29	49	37	5	370	99	69	58	NA	89
Iron	2003 Mean	22,165*	17,100*	10,565	13,306	51,809*	22,353	8,616*	25,932	30,249	35,778	21,996	27,567	35,311
	Max	22,165*	17,100*	14,277	14,277	51,809*	32,459	8,616*	35,469	34,576	36,008	22,218	31,211	36,406
	2007 Mean	23,249	16,172*	12,809	10,391	39,573	19,122	4,314	18,303	26,256	32,910	16,262	NA	32,189
	Max	24,667	16,172*	13,991	10,757	45,305	28,442	4,351	24,231	27,990	37,614	19,014	NA	32,546
Lead	2003 Mean	87*	62*	41	52	112*	116	129*	505	246	141	178	231	280
	Max	87*	62*	71	71	112*	137	129*	669	346	163	218	278	337
	2007 Mean	58	58*	19	42	104	90	15	324	221	116	157	NA	260
	Max	63	58*	19	56	123	113	15	467	334	161	250	NA	301
Manganese	2003 Mean	415*	433*	222	331	894*	716	678*	472	603	1,864	446	501	552
	Max	415*	433*	321	340	894*	929	678*	734	607	3,167	495	529	595
	2007 Mean	400	432*	265	305	945	656	389	310	630	1,808	345	NA	480
	Max	442	432*	316	324	1,123	835	468	381	632	3,178	407	NA	488
Mercury	2003 Mean	0.277*	0.106*	0.163	0.241	0.061*	0.075	0.217	1.499	3.525	0.229	0.339	0.271	0.333
	Max	0.277*	0.106*	0.173	0.308	0.061*	0.084	0.351	1.907	6.397	0.350	0.401	0.330	0.349
	2007 Mean	0.200	0.243*	0.031	0.393	0.124	0.058	0.010	1.381	0.463	<0.006	0.141	NA	0.347
	Max	0.223	0.243*	0.035	0.596	0.148	0.092	0.012	1.899	0.475	<0.006	0.175	NA	0.404
Nickel	2003 Mean	43*	29*	14	23	26*	24	8*	40	29	29	28	26	38
	Max	43*	29*	22	24	26*	37	8*	49	32	38	30	28	42
	2007 Mean	28	20*	14	14	24	16	4	23	27	16	16	NA	30
	Max	31	20*	14	15	25	25	4	30	29	19	18	NA	32

TABLE BII-1 (Continued): MEAN AND MAXIMUM CONCENTRATIONS OF METALS IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

Metal[1]	Year	LCR-S[2]		Thorn Cr.		Calumet R.		Indian Cr.	GCR[3]	LCR-N[4]		Calumet-Sag Channel		
		52	57	54	97	49	55	50	86	56	76	58	59	43
Silver	2003 Mean	1.6*	0.6*	<0.5	<0.5	0.7*	0.5	<0.3*	7.1	1.4	0.7	1.1	1.4	2.2
	Max	1.6*	0.6*	0.6	0.6	0.7*	0.5	<0.3*	10.0	1.7	0.8	1.2	1.8	2.3
	2007 Mean	<1.0	<1.0*	<1.0	<1.0	<1.0	<1.0	<1.0	2.0	<1.0	<1.0	<1.0	NA	<1.0
	Max	<1.0	<1.0*	<1.0	<1.0	<1.0	<1.0	<1.0	3.0	<1.0	<1.0	<1.0	NA	<1.0
Zinc	2003 Mean	319*	230*	255	145	296*	327	258*	1,762	465	318	460	975	1,072
	Max	319*	230*	313	197	296*	514	258*	2,427	526	372	465	1,322	1,359
	2007 Mean	286	248*	97	106	242	247	38	1,159	347	373	268	NA	884
	Max	310	248*	140	131	254	378	42	1,677	382	384	290	NA	1,099

[1]Concentrations expressed as mg/kg dry weight.
[2]Little Calumet River South.
[3]Grand Calumet River.
[4]Little Calumet River North.
[5]Calumet-Sag Channel.
*Only one data point available.
NA = Not available.

APPENDIX BIII

MEAN AND MAXIMUM VALUES OF ACID VOLATILE SULFIDES, SIMULTANEOUSLY EXTRACTED METALS, TOTAL ORGANIC CARBON, AND PARTICLE SIZE IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

TABLE BIII-1: MEAN AND, MAXIMUM, CONCENTRATIONS OF ACID VOLATILE SULFIDES, SIMULTANEOUSLY EXTRACTED METALS, AND THE RATIO OF SIMULTANEOUSLY EXTRACTED METALS TO ACID VOLATILE SULFIDES IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

		Acid Volatile Sulfides[1]				Simultaneously Extracted Metals[1]				SEM/AVS[2]			
		2003		2007		2003		2007		2003		2007	
Location	Waterway	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Wentworth Ave.	LCR-S[3]	38.05*	38.05*	43.65	49.90	4.82*	4.82*	4.85	5.30	0.13*	0.13*	0.10	0.10
Ashland Ave.	LCR-S	3.81*	3.81*	34.30*	34.30*	6.06*	6.06*	4.40*	4.40*	1.59*	1.59*	0.10*	0.10*
Joe Orr Rd.	Thorn Cr.	21.01	33.54	1.10*	1.10*	2.33	3.23	1.15	1.70	0.14	0.17	1.50*	1.50*
170th St.	Thorn Cr.	29.40	58.29	3.55	5.00	2.46	3.62	1.80	2.30	1.32	2.58	0.55	0.60
Ewing Ave.	Calumet R.	3.36*	3.36*	3.95	5.30	4.05*	4.05*	3.60	3.60	1.21*	1.21*	1.05	1.40
130th St.	Calumet R.	0.72	1.20	7.45	9.00	3.23	5.51	3.65	5.70	<11.88	22.96	0.60	1.00
Burnham Ave.	Indian Cr.	18.74	24.98	5.95	7.20	2.80	3.48	0.60	0.60	0.18	0.28	0.10	0.10
Burnham Ave.	GCR[4]	164.42	273.40	65.50	74.90	7.06	7.84	19.10	22.70	0.08	0.14	0.30	0.40
Indiana Ave.	LCR-N[5]	19.96	32.60	5.55	8.30	11.24	17.85	6.65	8.00	0.59	0.63	1.45	1.90
Halsted St.	LCR-N	9.87	12.07	13.30	23.10	5.52	6.65	4.45	5.60	0.56	0.57	0.55	0.90
Ashland Ave.	CSC[6]	41.65	56.26	10.55	13.60	23.62	30.22	4.60	5.00	0.58	0.63	0.50	0.60
Cicero Ave.	CSC	26.40	40.80	NA	NA	16.90	25.27	NA	NA	0.67	0.71	NA	NA
Route 83	CSC	36.32	43.80	33.10	42.10	17.75	24.20	13.35	16.30	0.47	0.55	0.40	0.40

[1]Concentrations expressed as µmoles/g.
[2]Ratio of Simultaneously Extracted Metals to Acid Volatile Sulfides.
[3]Little Calumet River South.
[4]Grand Calumet River.
[5]Little Calumet River North.
[6]Calumet-Sag Channel.
*Only one data point available.
NA = Not available.

TABLE BIII-2: MEAN AND MAXIMUM TOTAL ORGANIC CARBON CONCENTRATIONS AND PERCENT GRAVEL IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

Station			Total Organic Carbon[1]				Percent Gravel			
			2003		2007		2003		2007	
No.	Location	Waterway	Mean	Max	Mean	Max	Mean	Max	Mean	Max
52	Wentworth Avenue	Little Calumet River South	930*	930*	21,000	24,000	8.0*	8.0*	2.7	4.3
57	Ashland Avenue	Little Calumet River South	24,000*	24,000*	25,000*	25,000*	14.0*	14.0*	1.0*	1.0*
54	Joe Orr Rd.	Thorn Creek	5,000	5,800	5,800	6,400	19.0	37.0	21.0	32.7
97	170th St.	Thorn Creek	44,450	80,000	10,850	15,000	3.0	3.0	6.8	11.9
49	Ewing Avenue	Calumet River	25,000*	25,000*	24,333	27,000	9.0*	9.0*	9.9	20.0
55	130th Street	Calumet River	19,550	33,000	12,850	20,000	0.5	1.0	5.6	6.2
50	Burnham Avenue	Indian Creek	62,900	120,000	4,300	4,700	6.0	10.0	0.3	0.3
86	Burnham Avenue	Grand Calumet River	2,450	3,900	42,500	53,000	0.0	0.0	2.1	3.2
56	Indiana Avenue	Little Calumet River North	16,900	24,000	27,500	28,000	6.5	12.0	3.8	5.7
76	Halsted Street	Little Calumet River North	12,050	17,000	22,000	28,000	2.5	5.0	11.1	21.6
58	Ashland Avenue	Calumet-Sag Channel	870	1,300	9,700	17,000	0.0	0.0	7.5	10.2
59	Cicero Avenue	Calumet-Sag Channel	30,000	37,000	NA	NA	0.5	1.0	NA	NA
43	Route 83	Calumet-Sag Channel	64,500	86,000	36,500	37,000	0.5	1.0	0.0	0.0

[1]Concentrations expressed as mg/kg dry weight.
*Only one data point available.
NA = Not available.

TABLE BIII-3: MEAN AND MAXIMUM PERCENT SAND, SILT, AND CLAY IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

		Percent Sand				Percent Silt				Percent Clay			
		2003		2007		2003		2007		2003		2007	
Location	Waterway	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Wentworth Ave.	LCR-S[1]	42.0*	42.0*	17.9	26.2	45.0*	45.0*	63.0	64.9	5.0*	5.0*	16.5	24.5
Ashland Ave.	LCR-S	44.0*	44.0*	47.5*	47.5*	36.0*	36.0*	42.8*	42.8*	6.0*	6.0*	8.7*	8.7*
Joe Orr Rd.	Thorn Cr.	77.0	93.0	74.6	83.8	3.5	6.0	2.0	3.2	1.0	1.0	2.1	2.9
170th St.	Thorn Cr.	71.0	80.0	75.3	83.8	19.5	27.0	14.6	26.0	6.5	8.0	3.8	6.6
Ewing Ave.	Calumet R.	58.0*	58.0*	65.7	70.2	22.0*	22.0*	13.3	21.9	11.0*	11.0*	10.7	16.1
130th St.	Calumet R.	62.0	84.0	72.9	87.4	26.5	41.0	11.3	18.2	11.0	19.0	10.2	18.4
Burnham Ave.	Indian Cr.	48.0	84.0	96.9	97.1	43.0	75.0	1.8	2.1	3.0	3.0	1.2	1.7
Burnham Ave.	GCR[2]	72.5	85.0	67.3	72.6	24.5	37.0	24.9	29.2	3.0	3.0	5.8	7.9
Indiana Ave.	LCR-N[3]	48.0	70.0	34.3	46.4	37.0	59.0	35.7	45.1	8.5	14.0	26.2	30.7
Halsted St.	LCR-N	60.0	85.0	83.8	90.9	30.0	53.0	3.2	5.3	7.0	11.0	2.0	3.3
Ashland Ave.	CSC[4]	53.0	70.0	64.8	80.8	41.0	55.0	19.9	34.0	6.0	9.0	7.9	12.5
Cicero Ave.	CSC	36.5	51.0	NA	NA	48.0	58.0	NA	NA	15.0	19.0	NA	NA
Route 83	CSC	10.5	12.0	9.8	12.3	52.5	63.0	45.9	48.5	36.5	48.0	44.4	44.5

[1]Little Calumet River South.
[2]Grand Calumet River.
[3]Little Calumet River North.
[4]Calumet-Sag Channel.
*Only one data point available.
NA = Not available.

APPENDIX BIV

MEAN AND MAXIMUM VALUES OF ORGANIC PRIORITY POLLUTANTS IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

TABLE BIV-1: MEAN AND MAXIMUM CONCENTRATIONS OF TOTAL POLYCYCLIC AROMATIC HYDROCARBONS, POLYCHLORINATED BIPHENYLS, AND DIELDRIN IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

		Total PAHs[1]				Total PCBs[1]				Dieldrin[1]			
		2003		2007		2003		2007		2003		2007	
Location	Waterway	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Wentworth Ave.	LCR-S[2]	40,801*	40,801*	35,581	43,540	405*	405*	<30	<30	<2*	<2*	<5	<5
Ashland Ave.	LCR-S	6,160*	6,160*	35,216*	35,216*	618*	618*	<30[a]	<30[a]	19*	19*	<5*	<5*
Joe Orr Rd.	Thorn Cr.	<1,470	<1,470	12,129	19,319	<10	<10	<464	897	<2	<2	<5	<5
170th St.	Thorn Cr.	11,939	12,788	6,224	8,009	3,993	4,979	<463	895	45	46	<5	<5
Ewing Ave.	Calumet R.	12,540*	12,540*	5,482	5,814	1,028*	1,028*	<30	<30	<2	<2	<5	<5
130th St.	Calumet R.	<1,470	<1,470	10,214	19,161	<1,581	3,152	<595	1,160	<2	<2	<5	<5
Burnham Ave.	Indian Cr.	3,675	4,766	<2,621	<4,400	<10	<10	<30	<30	<2	<2	<5	<5
Burnham Ave.	GCR[3]	80,644	100,076	119,228	201,140	1,350	1,503	<30	<30	<14	25	<5	<5
Indiana Ave.	LCR-N[4]	25,801	39,562	7,783	11,329	<411	812	<30	<30	<2	<2	<5	<5
Halsted St.	LCR-N	27,053	38,451	11,260	18,282	<121	232	<30	<30	<2	<2	<5	<5
Ashland Ave.	CSC[5]	17,626	18,079	62,111	110,120	1,156	1,435	<30	<30	<2	<2	<5	<5
Cicero Ave.	CSC	36,375	39,142	30,182	35,060	6,445	11,419	<30	<30	<7	12	<5	<5
Route 83	CSC	14,672	14,749	12,853	17,330	3,084	4,648	<3,710	<30	<2	<2	<5	<5

[1]Concentrations expressed as µg/kg.
[2]Little Calumet River South.
[3] Grand Calumet River.
[4]Little Calumet River North.
[5]Calumet-Sag Channel.
*Only one data point available.
PAHs = Polycyclic Aromatic Hydrocarbons.
PCBs = Polychlorinated Biphenyls.
NA = Not available.

TABLE BIV-2: MEAN AND MAXIMUM OF THE SUM OF DICHLORODIPHENYLDICHLOROETHANE, DICHLORODIPHENYLDICHLOROETHYLENE, AND DICHLORODIPHENYLTRICHLOROETHANE CONCENTRATIONS IN CALUMET RIVER SYSTEM SEDIMENTS DURING 2003 AND 2007

Location	Waterway	Sum DDD[1]				Sum DDE[1]				Sum DDT[1]			
		2003		2007		2003		2007		2003		2007	
		Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Wentworth Ave.	LCR-S[2]	17*	17*	<13	22	<2*	<2*	15	29	<2*	<2*	<8	18
Ashland Ave.	LCR-S	25*	25*	91*	91*	20*	20*	14*	14*	20*	20*	47*	47*
Joe Orr Rd.	Thorn Cr.	<2	<2	<5	<5	<2	<2	<5	<5	<2	<2	<5	<5
170th St.	Thorn Cr.	48	63	26	29	<2	<2	<7	9	24	29	<8	11
Ewing Ave.	Calumet R.	<2*	<2*	<5	<5	<2*	<2*	<5	<5	<2*	<2*	<5	<5
130th St.	Calumet R.	<2	<2	<5	<5	<2	<2	<5	<5	<10	17	<5	<5
Burnham Ave.	Indian Cr.	<15	28	<5	<5	<2	<2	<5	<5	<36	69	<5	<5
Burnham Ave.	GCR[3]	86	91	22	27	46	60	<5	<5	294	536	<13	22
Indiana Ave.	LCR-N[4]	<6	10	<5	<5	<2	<2	<5	<5	<8	13	<5	<5
Halsted St.	LCR-N	<2	<2	<5	<5	<2	<2	<5	<5	<5	8	<5	<5
Ashland Ave.	CSC[5]	<2	<2	<5	<5	20	23	<11	17	<2	<2	<5	<5
Cicero Ave.	CSC	45	59	<13	20	79	131	46	77	<14	25	<5	<5
Route 83	CSC	28	29	<5	<5	52	65	<60	114	<2	<2	<5	<5

DDD = Dichlorodiphenyldichloroethane.
DDE = Dichlorodiphenyldichloroethylene.
DDT = Dichlorodiphenyltrichloroethane.
[1]Concentrations expressed as µg/kg.
[2]Little Calumet River South.
[3]Grand Calumet River.
[4]Little Calumet River North.
[5]Calumet-Sag Channel.
*Only one data point available.
NA = Not available.

APPENDIX C

BENTHIC MACROINVERTEBRATE COMMUNITY COMPOSITION OF EACH WATERWAY IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2010

TABLE C-1: PERCENT BENTHIC MACROINVERTEBRATE COMPOSITION OF WATERWAYS IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2010

Invertebrate Taxa	Calumet River	Little Calumet River North	Calumet-Sag Channel	Little Calumet River South	Thorn Creek	Indian Creek	Grand Calumet River
Annelida	2.7	68.4	83.1	66.1	52.0	48.1	99.99
Arachnoidea	0.002	0.0	0.0	0.0	0.01	0.0	0.0
Coelenterata	1.5	3.1	1.3	2.0	0.7	0.0	0.0
Crustacea	1.6	2.6	1.2	4.1	5.5	5.6	0.01
Ectoprocta	0.002	0.002	0.002	0.0	0.0	0.0	0.0
Gastropoda	0.1	0.6	0.5	4.5	3.7	0.0	0.0
Insecta	0.8	7.5	10.0	5.3	34.73	46.1	0.0
Nemertea	0.0002	0.0	0.0	0.0	0.0	0.0	0.0
Bivalvia	93.3	16.6	3.6	8.3	2.7	0.0	0.0
Platyhelminthes	0.003	1.2	0.2	9.8	0.7	0.2	0.0
Porifera	0.0	0.001	0.0	0.0	0.0	0.0	0.0

APPENDIX D

RELATIVE ABUNDANCE OF FISH SPECIES IN CALUMET RIVER SYSTEM WATERWAYS

TABLE D-1: PERCENT ABUNDANCE OF FISH SPECIES IN WATERWAYS IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2012

Fish Species	Calumet River	Little Calumet River North	Calumet-Sag Channel	Little Calumet River South	Thorn Creek	Indian Creek	Grand Calumet River
Banded killifish	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Black buffalo	0.6	0.2	0.0	0.0	0.0	0.0	0.0
Black bullhead[1]	0.0	0.2	0.1	0.0	0.0	0.0	0.0
Black crappie[1]	0.03	0.3	0.03	0.6	0.0	0.0	0.0
Bluegill[1]	3.3	6.9	1.7	4.1	4.3	7.5	11.1
Bluntnose minnow	19.4	3.6	7.5	2.2	0.0	83.8	0.0
Brook silverside	0.8	0.2	1.0	0.0	0.0	2.3	0.0
Brown bullhead[1]	0.0	0.1	0	0.0	0.0	0.0	0.0
Central mudminnow	0.0	0.1	0	0.0	0.0	0.0	0.0
Channel catfish[1]	0.0	0.07	0.1	0.0	2.2	0.0	0.0
Chinook salmon[1]	0.03	0.02	0	0.0	0.0	0.0	0.0
Common carp	3.9	11.5	10.4	15.6	9.8	0.1	38.9
Common carp x Goldfish	0.1	0.03	0	0.6	0.0	0.0	0.0
Creek chub	0.0	0.0	0.9	0.0	16.3	0.0	0.0
Emerald shiner	9.8	5.1	9.2	1.6	0.0	0.1	0.0
Fathead minnow	0.3	0.7	0.5	0.3	0.0	0.0	0.0
Freshwater drum	0.3	0.3	0.6	0.0	0.0	0.0	0.0
Gizzard shad	24.9	35.4	37.2	57.5	1.1	0.0	33.3
Golden shiner	0.1	2.7	18.2	1.3	0.0	0.2	0.0
Goldfish	0.03	4.2	0.4	3.2	0.0	0.0	11.1
Grass carp	0.03	0.0	0.0	0.0	0.0	0.0	0.0
Grass pickerel[1]	0.0	0.02	0.0	0.6	1.1	0.2	0.0
Green sunfish[1]	0.8	1.1	2.9	4.4	47.8	0.6	0.0
Hybrid sunfish	0.0	0.03	0.2	0.0	0.0	0.0	0.0
Johnny darter	0.0	0.0	0.0	0.0	1.1	0.0	0.0
Largemouth bass[1]	11.3	9.7	6.3	2.2	1.1	0.2	0.0

TABLE D-1 (Continued): PERCENT ABUNDANCE OF FISH SPECIES IN WATERWAYS IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2012

Fish Species	Calumet River	Little Calumet River North	Calumet-Sag Channel	Little Calumet River South	Thorn Creek	Indian Creek	Grand Calumet River
Mosquitofish	0.0	0.0	0.03	0.0	0.0	0.0	0.0
Northern longear sunfish[1]	0.0	0.0	0.0	0.0	0.0	3.4	0.0
Northern pike[1]	0.03	0.03	0.0	0.0	0.0	0.0	0.0
Orangespotted sunfish[1]	0.03	0.02	0.0	0.6	0.0	0.0	0.0
Pumpkinseed[1]	2.3	9.4	0.5	0.3	0.0	0.4	0.0
Quillback	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Rock bass[1]	6.1	0.0	0.0	0.0	0.0	0.0	0.0
Round goby	2.2	0.6	0.1	0.6	2.2	0.1	0.0
Sand shiner	0.03	0.02	0.03	0.0	0.0	0.0	0.0
Skipjack herring	0.0	0.02	0.0	0.0	0.0	0.0	0.0
Smallmouth bass[1]	10.1	0.1	0.03	0.0	0.0	0.4	0.0
Smallmouth buffalo	0.1	0.02	0.0	0.0	0.0	0.0	0.0
Spotfin shiner	0.4	0.2	0.5	0.3	0.0	0.0	0.0
Spottail shiner	0.0	0.1	0.0	0.0	0.0	0.4	0.0
White bass[1]	0.0	0.02	0.0	0.0	0.0	0.0	0.0
White crappie[1]	0.0	0.26	0.03	0.3	0.0	0.0	5.6
White perch[1]	0.3	1.5	0.6	0.0	0.0	0.0	0.0
White sucker	1.3	2.6	0.0	1.9	6.5	0.1	0.0
Yellow bass[1]	0.1	0.7	0.3	0.0	0.0	0.0	0.0
Yellow bullhead[1]	0.03	1.5	0.7	1.6	6.5	0.0	0.0
Yellow perch[1]	0.5	0.4	0.0	0.0	0.0	0.1	0.0

[1]Game fish species.

APPENDIX E

TREND ANALYSIS OF WATER QUALITY PARAMETERS AT STATIONS WITHIN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2012

TABLE E-1: TOTAL SUSPENDED SOLIDS SIGNIFICANCE TEST FOR POPULATION CHARACTERISTICS AND OVERALL TREND AT AMBIENT WATER QUALITY MONITORING STATIONS IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2012

Station	Tests				Trend Analysis[1]		
No.	P[2]	DF[3]	EDF[4]	P[5]	P[6]	Trend	Use[7]
49	0.470	11	100	0.241	0.023	Negative	0
50	0.364	11	120	0.593	0.995	No Trend	0
55	0.363	11	109	0.023	0.000	Negative	1
86	0.426	11	102	0.417	0.449	No Trend	0
56	0.241	11	104	0.000	0.000	Negative	1
76	0.705	11	124	0.201	0.000	Negative	0
52	0.222	11	110	0.016	0.121	No Trend	1
54	0.160	11	88	0.134	0.161	No Trend	0
97	0.156	11	111	0.083	0.080	No Trend	0
57	0.186	11	113	0.212	0.873	No Trend	0
58	0.313	11	121	0.218	0.639	No Trend	0
59	0.920	11	121	0.360	0.588	No Trend	0
43	0.465	11	119	0.104	0.003	Negative	0

[1]Trend analysis is conducted by Mann-Kendall non-parametric method.
[2]Test for equality of yearly variances of each location.
[3]Class (Year) degrees of freedom.
[4]Error degrees of freedom.
[5]Test for equality of yearly means of each location.
[6]Test for determination of overall trend.
[7]Consideration of Trend (1 = need to consider, otherwise no need to consider).

TABLE E-2: AMMONIA NITROGEN SIGNIFICANCE TEST FOR POPULATION CHARACTERISTICS AND OVERALL TREND AT AMBIENT WATER QUALITY MONITORING STATIONS IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2012

Station	Tests				Trend Analysis[1]		
No.	P[2]	DF[3]	EDF[4]	P[5]	P[6]	Trend	Use[7]
49	0.828	11	100	0.000	0.017	Negative	1
50	0.056	11	120	0.007	0.139	No Trend	1
55	0.539	11	109	0.040	0.055	No Trend	1
86	0.107	11	102	0.002	0.000	Positive	1
56	0.558	11	103	0.444	0.328	No Trend	0
76	0.322	11	124	0.189	0.001	Positive	0
52	0.250	11	110	0.449	0.511	No Trend	0
54	0.644	11	88	0.456	0.058	No Trend	0
97	0.131	11	111	0.032	0.004	Negative	1
57	0.436	11	113	0.001	0.076	No Trend	1
58	0.784	11	121	0.632	0.021	Positive	0
59	0.456	11	121	0.037	0.015	Positive	1
43	0.528	11	119	0.210	0.034	Positive	0

[1]Trend analysis is conducted by Mann-Kendall non-parametric method.
[2]Test for equality of yearly variances of each location.
[3]Class (Year) degrees of freedom.
[4]Error degrees of freedom.
[5]Test for equality of yearly means of each location.
[6]Test for determination of overall trend.
[7]Consideration of Trend (1 = need to consider, otherwise no need to consider).

TABLE E-3: DISSOLVED OXYGEN SIGNIFICANCE TEST FOR POPULATION CHARACTERISTICS AND OVERALL TREND AT CONTINUOUS DISSOLVED OXYGEN MONITORING STATIONS IN THE CALUMET RIVER SYSTEM BETWEEN 2001 AND 2012

		Tests				Trend Analysis[2]		
CDOM[1] Station	Waterway	P[2]	DF[3]	EDF[4]	P[5]	P[6]	Trend	Use[7]
Torrence Avenue	Grand Calumet River	0.482	9	102	0.559	0.301	No Trend	0
C&W Indiana Railroad	Little Calumet River North	0.439	11	126	0.914	0.039	Negative	0
Halsted Street	Little Calumet River North	0.205	11	126	0.067	0.002	Negative	0
Ashland Avenue	Little Calumet River South	0.656	11	126	0.954	0.249	No Trend	0
Wentworth Avenue	Little Calumet River South	0.919	6	49	0.045	0.529	No Trend	1
Division Street	Calumet-Sag Channel	0.295	4	39	0.093	0.620	No Trend	0
Cicero Avenue	Calumet-Sag Channel	0.530	10	105	0.661	0.862	No Trend	0
River Mile 311.7	Calumet-Sag Channel	0.229	4	39	0.169	0.895	No Trend	0
Southwest Highway	Calumet-Sag Channel	0.575	4	35	0.062	0.898	No Trend	0
104th Avenue	Calumet-Sag Channel	0.703	9	98	0.001	0.000	Negative	1
Route 83	Calumet-Sag Channel	0.870	11	132	0.868	0.347	No Trend	0

[1]Continuous Dissolved Oxygen Monitoring.
[2]Trend analysis is conducted by Mann-Kendall non-parametric method.
[3]Test for equality of yearly variances of each location.
[4]Class (Year) degrees of freedom.
[5]Error degrees of freedom.
[6]Test for equality of yearly means of each location.
[7]Test for determination of overall trend.
[8]Consideration of Trend (1 = need to consider, otherwise no need to consider).