

# **Comparative Analysis of Discharges into Lake Michigan Phase I—Southern Lake Michigan**

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**Environmental Science Division**

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prepared for  
Purdue University

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## Acronyms and Abbreviations

ADN	air deposition of nitrogen
AIRMoN-dry	Atmospheric Integrated Research Monitoring Network
Argonne	Argonne National Laboratory
ATSDR	U.S. Agency for Toxic Substances and Disease Registry
BAT	best available technology
BOD	biochemical oxygen demand)—check biological in my style sheet
BP	BP Products North America Inc.
CASTNet	Clean Air Status and Trends Network
CBOD <sub>5</sub>	five-day carbonaceous biochemical oxygen demand
CFR	<i>Code of Federal Regulations</i>
COD	chemical oxygen demand
Cr <sup>+3</sup>	trivalent chromium
Cr <sup>+6</sup>	hexavalent chromium
DL	detection level
DMR	discharge monitoring report
DNR	Department of Natural Resources
ECHO	Enforcement and Compliance History Online
ELG	effluent limitations guideline
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
GAO	Government Accountability Office
GIS	geographic information system
Hg	mercury
Hg <sub>T</sub>	total mercury
IARC	International Agency for Research on Cancer
IDEM	Indiana Department of Environmental Management
IEPA	Illinois Environmental Protection Agency
IND	industrial
LMMBP	Lake Michigan Mass Balance Project
MDEQ	Michigan Department of Environmental Quality
MeHg	methylmercury
MG	million gallons
MGD	million gallons per day
MUN	municipal
NADP	National Atmospheric Deposition Program
NAICS	North American Industry Classification System
NH <sub>3</sub>	ammonia
NH <sub>4</sub> <sup>+</sup>	ammonium
NO <sub>2</sub> <sup>+</sup>	nitrite
NO <sub>3</sub> <sup>+</sup>	nitrate
NOI	Notice of Intent
NPCP	Nonpoint Pollution Control Plan
NPDES	National Pollutant Discharge Elimination System
NSP	nonpoint source pollution

PCB	polychlorinated biphenyl
PCS	Permit Compliance System
Purdue	Purdue University–Calumet Water Institute
Se	selenium
TRI	Toxics Release Inventory
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
V	vanadium

### Units of Measure

µm	micrometer(s)
C	degree(s) Celsius
d	day(s)
g	gram(s)
gal	gallon(s)
ha	hectare(s)
kg	kilogram(s)
L	liter(s)
lb	pound(s)
mg	microgram(s)
mi	mile(s)
ng	nanogram(s)
ppm	part(s) per million
yr	year(s)

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## Executive Summary

BP Products North America Inc. (BP) owns and operates a petroleum refinery located on approximately 1,700 acres in Whiting, East Chicago, and Hammond, Indiana, near the southern tip of Lake Michigan. BP provided funding to Purdue University–Calumet Water Institute (Purdue) and Argonne National Laboratory (Argonne) to conduct studies related to wastewater treatment and discharges. Purdue and Argonne are working jointly to identify and characterize technologies that BP could use to meet the previous discharge permit limits for total suspended solids (TSS) and ammonia after refinery modernization. In addition to the technology characterization work, Argonne conducted a separate project task, which is the subject of this report.

In Phase I of a two-part study, Argonne estimated the current levels of discharge to southern Lake Michigan from significant point and nonpoint sources in Illinois, Indiana, and portions of Michigan. The study does not consider all of the chemicals that are discharged. Rather, it is narrowly focused on a selected group of pollutants, referred to as the “target pollutants.” These include: TSS, ammonia, total and hexavalent chromium, mercury, vanadium, and selenium. In Phase II of the study, Argonne will expand the analysis to cover the entire Lake Michigan drainage basin.

### ES.1 Point Sources

Point sources are discharges that enter water bodies through pipes, ditches, and other discrete conduits. Examples include industrial discharges, municipal wastewater treatment plant discharges, and some stormwater runoff. Point sources are regulated by state agencies under the National Pollutant Discharge Elimination System (NPDES) program. Many NPDES permits contain numeric limits for various pollutants, including some permits that limit the target pollutants. For those permits that require monitoring and reporting of effluent quality for the target pollutants, Argonne was able to quantify the discharges. In addition to the NPDES data, Argonne examined the U.S. Environmental Protection Agency’s (EPA’s) Toxics Release Inventory (TRI) program to get information on discharges of TRI chemicals to surface waters.

Argonne contacted the agencies with NPDES responsibility in each of the three states contributing to the Phase I study area. Each agency provided lists of facilities with NPDES permits. More than 430 facilities were subsequently evaluated. Argonne was able to exclude many of the facilities on those lists that did not have significant discharges of the target pollutants by applying different filtering mechanisms. After filtering, 80 facilities remained on the final list (21 industrial facilities and 59 municipal facilities).

Argonne used two different online databases maintained by the EPA to examine NPDES data from individual facilities. In addition, an Argonne representative visited the offices of the NPDES agencies in each state to review selected files. These sources of information, along with the original lists provided by the agencies, served as the source of the NPDES data collected for this study.

Three different types of data can be obtained through NPDES permit program records. Each of these offers different types of data and is likely to be found in the permit files to varying degrees:

- Application data often provide one-time analytical data on a wider range of pollutants than are normally limited in the permit. For some of the less common target pollutants, like chromium, vanadium, and selenium, this may be the only place where effluent data are available.
- Issued permits include numeric limits for different pollutants. The limits represent the highest allowable concentration of load for each pollutant that the facility may discharge. In composite form, this represents the total permitted load to the southern Lake Michigan drainage.
- Compliance monitoring data are collected at specified frequencies and reported monthly to the state agencies as discharge monitoring reports (DMRs). For those pollutants limited by the permits, ongoing monitoring data should be available, thereby allowing an accurate accounting of a facility's discharges over time. This allows averaging of the monthly results over a year or more.

## **ES.2 Nonpoint Sources**

Nonpoint source discharges enter water bodies in ways other than through discrete pipes or conduits. Nonpoint source pollution generally results from stormwater runoff (agricultural, urban, suburban), atmospheric contributions through rainfall and dry fall, drainage, seepage, groundwater exfiltration, or hydrologic modification. Nonpoint sources are not formally regulated by state environmental programs. Consequently, those sources are infrequently monitored. It is very difficult to quantify the amounts of pollutants that can be attributed to those nonpoint sources.

Nonpoint source information was collected through analysis of literature data. Most of the studies focused on geographic areas that were broader than the Phase I study area. The literature data were extrapolated to correspond to the size and location of the Phase I study area.

## **ES.3 Results and Discussion**

The point source data from the DMR data set is summarized in Table ES-1. Because the DMR data set reflects actual monitoring of the discharges during 2007, it is probably the best source of data for estimating point source loadings. The number of facilities that had available DMR data for each pollutant varies dramatically. Most facilities had TSS and ammonia data, but the data for metals were sparser. Data from the permit limits data set and the application data set (in Tables 7 and 8 of the report) showed mixed agreement with the DMR data set.

Table ES-1 Point Source Data from DMR Data Set

Pollutant	No. of Facilities with Available DMR Data	Average Phase I Area Combined Load (lb/day)	Maximum Phase I Area Combined Load (lb/day)
TSS	79	57,376	683,953
TSS (excluding highest value <sup>a</sup> )	79	43,688	235,348
Ammonia	64	2,245	10,406
Total chromium	17	11.8	51.3
Hexavalent chromium	3	1.8	2.5
Mercury	30	0.024	0.0686
Vanadium	1	No data available	0.117
Selenium	3	2.8	5.2

<sup>a</sup> The highest TSS monthly value was far higher than any other reported value. It dramatically skewed the TSS average and maximum values. This row of the table provides average and maximum TSS values excluding the single high value.

The TSS average and maximum loading data reflect a very strong influence of an unusually high TSS discharge during one month. Argonne contacted the state regulatory agency to confirm the validity of the high TSS value. The agency contact person verified that the data value appeared to be correct, although there may have been other contributing factors going on that were not readily apparent. Tables ES-1 and ES-2 both include an extra row to show the TSS loadings if the single highest TSS value is excluded from the data set.

Point source data collected from the TRI system had less relevance because only a few industrial and no municipal facilities reported releases of the target pollutants to surface waters. Eleven facilities did report TRI data for the relevant chemicals; some reported more than 1 chemical. In all, 20 release entries covering 6 chemicals were found. However, in the absence of much DMR data for vanadium, the TRI data reported for vanadium compounds was a useful addition to the DMR data.

Nonpoint source data were collected for TSS, ammonia, total nitrogen, and mercury, but almost no nonpoint source data exist for the other pollutants. The nonpoint source estimated average loads are shown in Table ES-2 in comparison with the average point source loads.

The TSS and mercury loads from nonpoint sources are more than one order of magnitude higher than the point source loads. The ammonia loads are higher from point sources, but if the nonpoint total nitrogen load is considered too, the combined nitrogen input (ammonia plus total nitrogen) from nonpoint sources is much higher.

**Table ES-2 Comparison of Point and Nonpoint Source Loads to the Phase I Study Area**

<b>Pollutant</b>	<b>Average Point Source Estimate (lb/day)</b>	<b>Average Nonpoint Source Estimate (lb/day)</b>
TSS	57,376	8,200,000
TSS excluding high value <sup>a</sup>	43,688	8,200,000
Ammonia	2,245	619
Total chromium	11.8	No data
Hexavalent chromium	1.8	No data
Mercury	0.024	0.67
Vanadium	26.6 <sup>b</sup>	No data
Selenium	2.8	No data
Total nitrogen	No data	28,000

<sup>a</sup> See footnote (a) in Table ES-1.

<sup>b</sup> The vanadium value is taken from the TRI data set rather than from the DMR data set.

Many other sources of pollutants that remain unquantified or poorly quantified (e.g., urban runoff, combined sewer overflows, groundwater exfiltration into surface water bodies, sediment re-release of metals into the overlying water column, excrement from birds and fish) make substantial contributions of the target pollutants.

The discharges from BP's Whiting refinery are substantial, but are not the highest or the only point source contributor to the Phase I study area. Other large industries and municipal wastewater treatment facilities discharge comparable or higher loads of the target pollutants.

## Chapter 1 Introduction

### 1.1 Background

BP Products North America Inc. (BP) owns and operates a petroleum refinery located on approximately 1,700 acres in Whiting, East Chicago and Hammond, Indiana near the southern tip of Lake Michigan. Whiting is located in the northwest corner of Indiana near the Illinois border. The refinery employs approximately 1,300 people and produces a variety of products including gasoline of all grades, diesel fuel, heating fuel, jet fuel, asphalt, and coke. The refinery can process up to 420,000 barrels of crude oil per day.

The Indiana Department of Environmental Management (IDEM) recently renewed National Pollutant Discharge Elimination System (NPDES) Permit No. IN0000108 for BP's Whiting Refinery. This permit, effective August 1, 2007, regulates the discharge of process wastewater, stormwater and noncontact cooling water from Outfalls 001, 002, and 005 to Lake Michigan and the discharge of stormwater through Outfalls 003 and 004 into the Lake George Branch of the Indiana Harbor Ship Canal.

One of the aspects considered in renewing the permit was BP's plan to modify the refinery in order to process a higher percentage of heavy oil from Canada than the refinery currently processes. The refinery will be modified during the term of this permit. As a result of using the Canadian heavy oil as a feedstock, the quantity of ammonia, total suspended solids (TSS), and other constituents in the untreated wastewater will be higher than it was previously. Based on the application of EPA guidelines for effluent limitations appropriate for the modified refinery, BP sought higher discharge permit limits for ammonia and TSS. After an extended review of BP's request and rationale for the revision, IDEM agreed to increase the allowable discharge limits for ammonia and TSS. Various Illinois-based groups raised objections to the higher permit limits, but the permit was issued nonetheless. A copy of the permit and a supporting fact sheet that provides the rationale for the permit decision can be viewed at [http://www.in.gov/idem/files/bp\\_finalpermit.doc](http://www.in.gov/idem/files/bp_finalpermit.doc) and [http://www.in.gov/idem/files/bp\\_factsheet.doc](http://www.in.gov/idem/files/bp_factsheet.doc), respectively.

Issuance of the renewed permit created a great deal of controversy in neighboring Illinois. The Illinois/Indiana border is very near the Whiting refinery, and many residents, members of the press, and politicians objected to the increased allowance of pollutants that could be discharged to Lake Michigan. In the face of the vocal opposition to the permit, BP agreed to not discharge ammonia or suspended solids at levels higher than allowed under the prior permit. BP also announced plans to provide funding to Purdue University-Calumet Water Institute (Purdue) and Argonne National Laboratory (Argonne) to conduct studies related to wastewater treatment and discharges. Purdue and Argonne are working jointly to identify and characterize technologies that BP could use to meet the prior discharge permit limits for TSS and ammonia after refinery modernization.

## 1.2 Focus and Purpose of Study

In addition to the technology characterization work, Argonne conducted a separate project task, which is the subject of this report. Argonne evaluated current levels of discharge to Lake Michigan from significant point and nonpoint sources. The study does not consider all of the hundreds of chemicals that are discharged. Rather, it is narrowly focused on a selected group of pollutants (referred to as the “target pollutants”—see Chapter 2).

The purpose of this study is to develop an inventory of the significant sources of target pollutants entering Lake Michigan. In addition to evaluating the discharges entering the lake directly, Argonne examined discharges on tributary streams and rivers flowing into Lake Michigan in the target study area.

The southern portion of Lake Michigan contains substantial population and industrial development. Although the Whiting refinery is a large discharger, it is not the only significant source of pollutants entering the lake. The Phase I inventory helps to evaluate the BP discharge in the context of a local and regional pollutant loading. The inventory of pollutant sources also allows some comparative analysis of key pollutant sources.

## 1.3 Content of Report

This chapter provides background information on the issue being addressed by the study and reviews the focus and purpose of the study. Chapter 2 describes the design and scope of the study, and provides information relating to the target pollutants on which the study focuses.

Chapter 3 describes the types of point source data that were evaluated and how the data were collected, filtered, and analyzed. Chapter 4 presents the point source data results in summary form. Chapter 5 describes the nonpoint source contributions to the study area. The sources of data are explained, and nonpoint source loads are estimated.

Chapter 6 provides discussion of the data. It compares point sources and nonpoint sources of the target pollutants. It also includes thoughts on the completeness and uncertainty of the data sets that were collected for the study. Chapter 7 provides a review of the report’s findings and makes several conclusions.



## 2.2 Types of Discharges

The study tries to quantify all types of discharges, including point sources and nonpoint sources. These types of discharges are described below.

### 2.2.1 Point Sources

Point source discharges are discharges that enter water bodies through pipes, ditches, and other discrete conduits. Examples include industrial discharges, municipal wastewater treatment plant discharges, and some stormwater runoff. Point sources are regulated by state agencies under the NPDES program. Many NPDES permits contain numeric limits for various pollutants. For those permits that require monitoring and reporting of effluent quality for the target pollutants, Argonne was able to quantify the discharges. Chapter 3 describes the types of data available from the state NPDES offices and how the data were evaluated.

In addition to the NPDES data, the U.S. Environmental Protection Agency's (EPA's) Toxics Release Inventory program requires companies that meet certain manufacturing, production, or use thresholds to submit data on annual releases of more than 600 toxic pollutants to different environmental media (e.g., air emissions, underground injection, discharges to surface).

### 2.2.2 Nonpoint Sources

Nonpoint source discharges enter water bodies in ways other than through discrete pipes or conduits. Nonpoint source pollution generally results from stormwater runoff (agricultural, urban, suburban), atmospheric contributions through rainfall and dry fall, drainage, seepage, groundwater exfiltration, or hydrologic modification. Nonpoint sources are not formally regulated by federal environmental programs. Consequently, those sources are infrequently monitored. It is very difficult to quantify the amounts of pollutants that can be attributed to nonpoint sources. Chapter 5 describes the information Argonne was able to compile relating to nonpoint source contributions to the Phase I study area.

### 2.2.3 Other Sources

Some types of discharges straddle the line between point and nonpoint sources. An important example of this is urban stormwater runoff. Some cities operate separate sewer systems: a) a sanitary sewer that conveys sewage to the municipal wastewater treatment plant; and b) a storm sewer that conveys stormwater directly to water bodies without treatment. Although municipalities must obtain NPDES permits for stormwater runoff, often those permits do not establish numeric limits. Instead they require best management practices that reduce the amount of contaminants that are released to water bodies. Therefore, data on the quantity of pollutants contained in stormwater runoff is minimal. Because of the volume and intensity of storms varies considerably, the pollutant releases are quite variable and sporadic.

Other cities have only a single set of sewer infrastructure, known as combined sewer systems. In these cities, stormwater enters sewer pipes that convey the stormwater to the municipal wastewater treatment plant along with sewage. When rainfall is low, the sewers can

accommodate the additional flow. However, when rainfall is heavy or intense over a short period, the stormwater runoff into the combined sewers exceeds the sewer capacity. Under those circumstances, these sewers typically have separate discharge points that allow release of the untreated mixture of sewage and stormwater runoff. These discharges are known as combined sewer overflows. While they are often identified in the NPDES permits, they are not necessarily limited or monitored on any regular basis.

Both types of sewer systems contribute significant loads of pollutants to water bodies, but in the absence of good data to characterize the volume and concentration of the discharges, they have not been included in the loading estimates for this study.

### 2.3 Target Pollutants

During early discussion with BP, the only target pollutants were TSS and ammonia. During later discussions, BP requested that the list of target pollutants be expanded to include several metals that were part of BP's new permit. The final list of target pollutants also included total chromium, hexavalent chromium, mercury, vanadium, and selenium. Each of these pollutants is described below. The summaries for ammonia and the metals are based on toxicological profiles prepared by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR). These can be downloaded from the agency's website.<sup>1</sup>

#### 2.3.1 TSS

Unlike the other target pollutants, TSS is not a specific chemical. Instead it represents a composite of all small particulates that are captured by a filter during a specific analytical test. The test measures the presence of solids but does not indicate the chemical nature of the solids. The solids could be sand, rust, dirt, metals, or other materials. The approved analytical method for TSS is to filter a water sample through a glass-fiber filter with pore size of 2 µm or less. The residue on the filter is heated in a furnace to a temperature of 103 to 105°C. The weight of the dried filter is compared to the weight of the new filter at the start of the test.

Suspended solids are present in municipal sanitary wastewater and many types of industrial wastewater. There are also nonpoint sources of suspended solids, such as soil erosion from agricultural and construction sites. As levels of suspended solids increase, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Some cold water species, such as trout and stoneflies, are especially sensitive to changes in dissolved oxygen. Photosynthesis also decreases, since less light penetrates the water. As less oxygen is produced by plants and algae, there is a further drop in dissolved oxygen levels.

Suspended solids settle to the bottom and can eventually blanket the river bed, damaging aquatic habitat. Suspended solids can smother the eggs of fish and aquatic insects, and can suffocate newly-hatched insect larvae. Suspended solids can also harm fish directly by clogging gills,

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<sup>1</sup> The URL is <http://www.atsdr.cdc.gov/toxpro2.html#bookmark05>, accessed April 8, 2008.

reducing growth rates, and lowering resistance to disease. Changes to the aquatic environment may result in a diminished food sources, and increased difficulties in finding food.

### 2.3.2 Ammonia

Ammonia is a chemical that is made both by humans and by nature. Ammonia is a colorless gas with a very sharp odor. Ammonia in this form is also known as ammonia gas or anhydrous ammonia. Ammonia gas can also be compressed and becomes a liquid under pressure. The odor of ammonia is familiar to most people because ammonia is used in smelling salts, household cleaners, and window cleaning products. Ammonia easily dissolves in water. In this form, it is also known as liquid ammonia, aqueous ammonia, or ammonia solution. In water, most of the ammonia ( $\text{NH}_3$ ) changes to the ionic form of ammonia, known as ammonium ions, which are represented by the formula  $\text{NH}_4^+$ . Ammonium ions are not gaseous and have no odor. Ammonia and ammonium ions can change back and forth in water. In wells, rivers, lakes, and wet soils, the ammonium form is the most common. Ammonia can also be combined with other substances to form ammonium compounds, including salts such as ammonium chloride, ammonium sulfate, ammonium nitrate, and others.

Ammonia is found in water, soil, and air, and is a source of much needed nitrogen for plants and animals. In high concentrations, ammonia can be toxic or harmful to aquatic life. Most states have established water quality standards for ammonia. However, at lower concentrations in water bodies, ammonia becomes a readily biodegradable chemical and a food source for phytoplankton and aquatic plants.

Ammonia does not last very long in the environment. The nitrogen portion of ammonia gets converted into some other type of nitrogen chemical or product (e.g., nitrate, nitrite, nitrogen gas). Ammonia does not build up in the food chain, but serves as a nutrient for plants and bacteria. Most of the ammonia in the environment comes from the natural breakdown of manure and dead plants and animals. Eighty percent of all manufactured ammonia is used as fertilizer. A third of this is applied directly to soil as pure ammonia. The rest is used to make other fertilizers that contain ammonium compounds, usually ammonium salts.

### 2.3.3 Total and Hexavalent Chromium

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases. Chromium is present in the environment in several different forms. The most common forms are elemental chromium, trivalent chromium ( $\text{Cr}^{+3}$ ), and hexavalent chromium ( $\text{Cr}^{+6}$ ). Trivalent chromium occurs naturally in the environment and is an essential nutrient required by the human body to promote the action of insulin in body tissues so that sugar, protein, and fat can be used by the body. Hexavalent chromium and elemental chromium are generally produced by industrial processes. Separate analytical methods are used to measure total and hexavalent chromium.

No known taste or odor is associated with chromium compounds. Elemental chromium is a steel-gray solid with a high melting point. It is used mainly for making steel and other alloys. The naturally occurring mineral chromite in the trivalent chromium form is used as brick lining for

high-temperature industrial furnaces, for making metals and alloys (mixtures of metals), and chemical compounds. Chromium compounds, mostly in trivalent or hexavalent forms, produced by the chemical industry are used for chrome plating, the manufacture of dyes and pigments, leather tanning, and wood preserving.

Chromium enters the air, water, and soil mostly in the trivalent and hexavalent forms as a result of natural processes and human activities. Emissions from burning coal and oil, and steel production can increase chromium levels in air. Various industrial discharges contain trivalent and hexavalent chromium. Chromium can be dissolved in the wastewater or can be present as suspended particulates that are measured as total suspended solids. Solid chromium particles eventually settle to the bottom of a water body and become part of the local sediment layer.

Hexavalent chromium is more toxic to humans and aquatic life than are other forms of chromium. The EPA has established separate water quality criteria for trivalent and hexavalent chromium, with the hexavalent criteria being considerably stricter. The U.S. Department of Health and Human Services has determined that certain hexavalent chromium compounds (calcium chromate, chromium trioxide, lead chromate, strontium chromate, and zinc chromate) are known human carcinogens. The International Agency for Research on Cancer (IARC) has determined that hexavalent chromium is carcinogenic to humans, based on sufficient evidence in humans for the carcinogenicity of hexavalent chromium compounds as found in chromate production, chromate pigment production, and chromium plating industries.

#### **2.3.4 Mercury**

Mercury occurs naturally in the environment and exists in several forms. These forms can be organized under three headings: elemental mercury, inorganic mercury, and organic mercury. Elemental mercury is a shiny, silver-white metal that is liquid at room temperature. Elemental mercury is the familiar liquid metal used in thermometers and some electrical switches. At room temperature, some of the metallic mercury will evaporate and form mercury vapors. Mercury vapors are colorless and odorless.

Inorganic mercury compounds occur when mercury combines with elements such as chlorine, sulfur, or oxygen. Most inorganic mercury compounds are white powders or crystals, except for mercuric sulfide (also known as cinnabar), which is red and turns black after exposure to light. When mercury combines with carbon, the compounds formed are called organic mercury compounds. The most common organic mercury compound in the environment is methylmercury.

Several forms of mercury occur naturally in the environment. The most common are elemental mercury, mercuric sulfide (cinnabar ore), mercuric chloride, and methylmercury. Some microorganisms (bacteria and fungi) and natural processes can change the mercury in the environment from one form to another. Methylmercury is of particular concern because it is highly toxic and can build up in certain edible freshwater and saltwater fish and marine mammals to levels that are many times greater than levels in the surrounding water (biomagnification).

Mercury enters the environment as the result of the normal breakdown of minerals in rocks and soil from exposure to wind and water, and from volcanic activity. Human activities since the start of the industrial age have resulted in the additional release of mercury to the environment. Estimates of the total annual mercury releases that result from human activities range from one-third to two-thirds of the total mercury releases. The levels of mercury in the atmosphere are very low and do not pose a health risk; however, the steady release of mercury has resulted in current levels that are three to six times higher than the estimated levels in the pre-industrial era atmosphere. Approximately 80% of the mercury released from human activities is elemental mercury released to the air, primarily from fossil fuel combustion, mining, and smelting, and from solid waste incineration.

According to EPA's mercury website,<sup>2</sup> after the mercury falls from the atmosphere, it can end up in streams, lakes, or estuaries, where it can be transferred to methylmercury through microbial activity. Methylmercury accumulates in fish at levels that may harm the fish and the other animals that eat them. Birds and mammals that eat fish are more exposed to methylmercury than any other animals in water ecosystems. Similarly, predators that eat fish-eating animals are at risk. Effects of methylmercury exposure on wildlife can include reduced fertility, slower growth and development and abnormal behavior that affect survival, and mortality, depending on the level of exposure. In addition, research indicates that the endocrine system of fish, which plays an important role in fish development and reproduction, may be altered by the levels of methylmercury found in the environment.

Mercury is given special attention by the EPA as a "bioaccumulative chemical of concern" under EPA's Great Lakes water quality guidance. EPA established stricter mercury water quality criteria for the Great Lakes and their tributaries than the criteria that apply to other U.S. waters. Each state with waters that drain to the Great Lakes was required to adopt state water quality standards that reflect the strict mercury criteria.

### **2.3.5 Vanadium**

Vanadium is a white to gray metal, often found as crystals. It has no particular odor. Vanadium occurs naturally in fuel oils and coal. In the environment it is usually combined with other elements such as oxygen, sodium, sulfur, or chloride. One manmade form, vanadium oxide, is most often used by industry, mostly in steelmaking. Vanadium oxide can be a yellow-orange powder, dark-grey flakes, or yellow crystals. Much smaller amounts are used in making rubber, plastics, ceramics, and other chemicals. The most likely way for the chemical to get into the air is when fuel oil is burned. When rocks and soil containing vanadium are broken down into dust by wind and rain, vanadium can get into the air, groundwater, surface water, or soil. It does not dissolve well in water, but it can be carried by the water, much as particles of sand might be carried. Vanadium is naturally found in soil and rocks at about 150 parts of vanadium per million parts of soil (150 ppm) in the earth's crust.

The EPA has not published any water quality criteria for vanadium. Vanadium is not commonly found in industrial discharges and is not generally limited by discharge permits. However, IDEM

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<sup>2</sup> The URL is <http://www.epa.gov/earlink1/mercury/index.htm>, visited on April 28, 2008.

did calculate Tier II aquatic life protection values for vanadium. These were used as the basis for the numeric limits for vanadium in BP's permit.

The major adverse health effect in humans from vanadium has been seen in workers exposed to large amounts of vanadium pentoxide dusts. Affected workers have coughs, chest pains, sore throats, and irritated eyes, but the symptoms disappear soon after exposure ceases. The response is similar to that of an upper respiratory tract infection. No other significant health effects of vanadium have been found. The gastrointestinal absorption of vanadium is so low that the health implications for people drinking the water are not readily apparent. There are no reports of death in humans following inhalation or oral or dermal exposure to vanadium. Humans are unlikely to be in contact with large enough amounts of vanadium to cause death.

### 2.3.6 Selenium

Selenium is a naturally occurring substance found in rocks and soil and in the earth's crust. Selenium, in its pure form of metallic gray to black crystals, is referred to as elemental selenium. Elemental selenium is commercially produced, primarily as a by-product of copper refining. Selenium is not often found in the environment in its elemental form, but is usually combined with other substances. Much of the selenium in rocks is combined with sulfide minerals or with silver, copper, lead, and nickel minerals. Selenium and its compounds are used in some photographic devices, gun bluing (a liquid solution used to clean the metal parts of a gun), plastics, paints, antidandruff shampoos, vitamin and mineral supplements, fungicides, and certain types of glass.

Weathering of rocks and soils may result in low levels of selenium in water, which may be taken up by plants. Weathering also releases selenium into the air on fine dust-like particles. Volcanic eruptions may release selenium in air. Selenium commonly enters the air from burning coal or oil. Selenium that may be present in fossil fuels combines with oxygen when burned, which may then react with water to form soluble selenium compounds. Airborne particles of selenium, such as in ash, can settle on soil or surface water.

In humans and animals, selenium is an essential nutrient that plays a role in protecting tissues from oxidative damage. Although selenium is an essential nutrient, exposure to high levels via inhalation or ingestion may cause adverse health effects. Selenium accumulates in many organ systems in the body; in general, the highest concentrations are found in the liver and kidneys. Upon contact with human skin, industrial selenium compounds have been reported to cause rashes, redness, heat, swelling, and pain. Brief, acute exposure of the eyes to selenium dioxide as a dust or fume in workplace air may result in burning, irritation, and tearing. However, only people who work in industries that process or use selenium or selenium compounds are likely to come into contact with levels high enough to cause eye irritation.

Selenium can be toxic to aquatic life (such as fish and invertebrates) where concentrations are excessive. It is also toxic to cormorants and other birds that consume aquatic organisms containing excessive levels of selenium. Selenium is sometimes referred to as a bioaccumulative pollutant, but it is not a "bioaccumulative chemical of concern" under EPA's Great Lakes water quality guidance. Aquatic life is exposed to selenium primarily through diet. Risks stem from

aquatic life eating food that is contaminated with selenium rather than from direct exposure to selenium in the water. Although selenium bioaccumulates in tissues of aquatic organisms, it is not significantly biomagnified.

#### **2.4 Geographical Information System Tool**

The Phase I report includes a description of the study, the approaches used to compile and analyze data, and estimated loads of the target pollutants. As part of Phase II of the study, Argonne plans to develop a GIS (geographical information system) tool that will allow users to graphically display discharge information in a map format. Typical GIS features, such as zooming capability and inclusion of various optional mapping layers, will be included in the final GIS tool.

## Chapter 3 Point Source Data Collection

The Phase I study area included discharges from portions of Illinois, Indiana, and Michigan. Argonne contacted the environmental agencies in each of these states as a starting point for data collection. In addition, Argonne met with water program personnel at EPA's Region V office in Chicago to assess what types of regional information could supplement the state information.

Each state provided information in a different format. Although all data were in spreadsheets, the categories of information differed among the agencies. In each case, the initial lists contained a large number of facilities, many of which were not relevant to formulation of target pollutant loads because of either the volume or chemical characteristics of the discharges at those facilities. The following sections describe, for each state, the nature of the initial information, the types of filtering that were used to remove facilities from the list, and the ways in which relevant data were extracted from files and online resources.

A brief review of the NPDES permit process is provided before the state-specific sections. Section 3.1 describes NPDES permits and the types of information that can be derived from three separate aspects of the NPDES program—permit applications, issued permits, and monitoring reports. Each of these offers different types of data and is likely to be found in the permit files to varying degrees:

- Application data typically represents actual discharge data, but is normally collected only once. It often includes data on a wider range of pollutants than are normally limited in the permit. For some of the less-common target pollutants, such as chromium, vanadium, and selenium, this may be the only place where effluent data are available.
- Issued permits include numeric limits for different pollutants. The limits represent the highest allowable concentration and/or load for each pollutant that the facility may discharge. In composite form, the permitted or calculated loads represent the total permitted load to the Lake Michigan drainage.
- Compliance monitoring data are collected at specified frequencies and reported monthly to the state agencies as discharge monitoring reports (DMRs). For those pollutants limited by the permits, ongoing monitoring data should be available, thereby allowing the most accurate accounting of a facility's discharges over time. This allows averaging of the monthly results over a year or more.

### 3.1 The NPDES Program

The NPDES permit program is a federal program assigned to the EPA under the Clean Water Act. NPDES permits are required for all point source discharges to surface water bodies. EPA can delegate the authority for administering the NPDES program to states that demonstrate the willingness and ability to manage the program. All four of the states bordering Lake Michigan have received authorization to administer the NPDES program.

### 3.1.1 Permit Limits

NPDES permits contain numeric discharge limits for various pollutants. They may also contain other operational and management requirements as well as general administrative and compliance requirements. Permit writers must calculate limits using two separate approaches and then apply the limits that are found to be more stringent.

The first approach calculates “technology-based limits.” The Clean Water Act specifies that industrial discharges must meet best available technology economically achievable (BAT). It is important to understand that EPA must select as the basis for BAT a technology that is already in use in a particular industry (or sometimes in a related industry) with a proven long-term track record of performance under the conditions associated with the type of discharge in question. Furthermore, the technology has to be affordable.

EPA has published effluent limitations guidelines (ELGs) for most large industrial categories. Where ELGs are available, permit writers use them to calculate technology-based limits. For example, the permit for BP’s Whiting refinery evaluated the ELGs from the petroleum refining industry; these are found at 40 CFR 419. These particular ELGs are based on the amount of feedstock processed by different units within the refinery. Production-based BAT limits are established for biochemical oxygen demand (BOD), chemical oxygen demand (COD), TSS, oil and grease, phenolic compounds, ammonia, sulfide, total chromium, and hexavalent chromium.

For municipal wastewater treatment plants, many of which are located in the Phase I study area, the national minimum technology-based discharge standard for municipal wastewater is referred to as “secondary treatment.” This term is defined at 40 CFR 133.102 (see below). The secondary treatment regulation uses the terms SS (same as TSS) and CBOD<sub>5</sub> (five-day carbonaceous biochemical oxygen demand).

*Sec. 133.102 Secondary treatment. The following paragraphs describe the minimum level of effluent quality attainable by secondary treatment in terms of the parameters—BOD<sub>5</sub>, SS and pH. All requirements for each parameter shall be achieved except as provided for in Sec. 133.103 and 133.105. [Note that these two sections refer to alternate ways of meeting secondary standards]*

*(a) BOD<sub>5</sub>.*

- (1) The 30-day average shall not exceed 30 mg/l.*
- (2) The 7-day average shall not exceed 45 mg/l.*
- (3) The 30-day average percent removal shall not be less than 85 percent.*
- (4) At the option of the NPDES permitting authority, in lieu of the parameter BOD<sub>5</sub> and the levels of the effluent quality specified in paragraphs (a)(1), (a)(2) and (a)(3), the parameter CBOD<sub>5</sub> may be substituted with the following levels of the CBOD<sub>5</sub> effluent quality provided:*
  - (i) The 30-day average shall not exceed 25 mg/l.*
  - (ii) The 7-day average shall not exceed 40 mg/l.*
  - (iii) The 30-day average percent removal shall not be less than 85 percent.*

*(b) SS.*

- (1) The 30-day average shall not exceed 30 mg/l.*

(2) *The 7-day average shall not exceed 45 mg/l.*

(3) *The 30-day average percent removal shall not be less than 85 percent.*

(c) *pH.*

*The effluent values for pH shall be maintained within the limits of 6.0 to 9.0 unless the publicly owned treatment works demonstrates that:*

*(1) Inorganic chemicals are not added to the waste stream as part of the treatment process; and*

*(2) contributions from industrial sources do not cause the pH of the effluent to be less than 6.0 or greater than 9.0.*

The second approach for calculating limits is known as “water quality-based limits.” Permit writers calculate the concentration of discharged pollutants at the edge of a mixing zone after any allowable dilution. These concentrations are compared to the state’s water quality standards for each pollutant. If any calculated concentrations exceed the water quality standards, stricter limits are developed for those pollutants. BP’s permit contains numeric limits derived from both technology-based and water quality-based limits.

### 3.1.2 Data from Permit Applications

Dischargers must submit permit applications before starting new discharges and within 180 days of the expiration of existing permits. Although each state may use a somewhat different application form for different groups of permits, large industrial dischargers must provide some analytical data describing their discharges on Application Form 2C. Form 2C lists nine pages of pollutants. Depending on the nature of the specific discharge, analyses must be provided for some or all of the pollutants through each point of discharge (referred to as an outfall).

In Form 2C, pages V-1 and V-3 contain the target pollutants. Copies of those pages from an actual industrial application (not BP’s) are shown in Figures 2 and 3.<sup>3</sup> The pages contain a great deal of information. This application is for the main outfall 001 at a facility that has multiple outfalls. Effluent data are provided for up to three sets of columns (maximum daily value, maximum 30-day value, and long-term average). Data are often reported separately in concentration and mass (loading). Where data were available, the reported long-term average loading value was used as the average load in the study database. The maximum daily loading value was used as the maximum load in the database.

Data for TSS and ammonia can be seen in Figure 2. TSS data are found on Part A, line d. Ammonia data are found in the next line. Data for total chromium, total mercury, and total selenium are found in Figure 3 on lines 5M, 8M, and 10M, respectively. Application form 2C does not require testing for hexavalent chromium or vanadium, thus no application data are available for those parameters. Figure 3 shows three columns under the heading A. The first column, “Testing Required,” refers to a list of toxic pollutants that must be measured on an industry-by-industry basis, as specified in the Form 2C instructions. The next two columns allow the applicant to indicate if each pollutant is believed to be present or absent. In the example

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<sup>3</sup> The images come from a second-hand scanned copy of the application and are not available at high resolution. They are included here to show an example of how actual data are filled in on the form. Readers can see a blank copy of Form 2C on EPA’s website at: <http://www.epa.gov/npdes/pubs/3510-2C.pdf>.

Figure 2 Page V-1 from NPDES Permit Application Form 2C

V. INTAKE AND EFFLUENT CHARACTERISTICS (continued from page 9 of form 2-C)											OUTFALL NO.	
PART A: You must provide the results of at least one analysis for every pollutant in this table. Complete one table for each outfall. See instructions for additional details.											001	
1. POLLUTANT	2. EFFLUENT						3. UNITS (specify if blank)		4. INTAKES (optional)			
	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVG. VALUE (if available)		d. NO. OF ANALYSES	a. LONG TERM AVG. VALUE		b. NO. OF ANALYSES		
	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS		(1) CONCENTRATION	(2) MASS			
a. Biochemical Oxygen Demand (BOD)	22.0	852			7.5	268	14	mg/L	lb/day			
b. Chemical Oxygen Demand (COD)	24.8	860					1	mg/L	lb/day			
c. Total Organic Carbon (TOC)	12.8	444					1	mg/L	lb/day			
d. Total Suspended Solids (TSS)	19.0	804	6.1	230	3.5	122	126	mg/L	lb/day			
e. Ammonia (as N)	0.160	5.55			J 0.051	J 1.80	14	mg/L	lb/day			
f. Flow	VALUE		VALUE		VALUE					VALUE		
	5.074		4.450		4.159		146	MGD				
g. Temperature (winter)	VALUE		VALUE		VALUE					VALUE		
	74.8		70.6		57.1		79	°F				
h. Temperature (summer)	VALUE		VALUE		VALUE					VALUE		
	82.0		79.0		76.8		27	°F				
i. pH	MINIMUM 6.7	MAXIMUM 8.6	MINIMUM 7.4	MAXIMUM 8.2			106	STANDARD UNITS				
PART B: Mark "X" in column 2-a for each pollutant you know or have reason to believe is present. Mark "X" in column 2-b for each pollutant you believe to be absent. If you mark column 2a for any pollutant which is limited either directly, or indirectly, but expressly, in an effluent limitation guideline, you must provide the results of at least one analysis for that pollutant. For other pollutants for which you mark column 2a, you must provide quantitative data or an explanation of their presence in your discharge. Complete one table for each outfall. See the instructions for additional details and requirements.												
1. POLLUTANT AND CAS NO. (if available)	2. MARK 'X'		3. EFFLUENT						4. UNITS		5. INTAKE (optional)	
	a. BELIEVED PRESENT	b. BELIEVED ABSENT	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVG. VALUE (if available)		d. NO. OF ANALYSES	a. LONG TERM AVG. VALUE		b. NO. OF ANALYSES
			(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS		(1) CONCENTRATION	(2) MASS	
a. Bromide (24859-87-6)		X	< 0.5	< 15					1	mg/L	lb/day	
b. Chlorine, Total Residual	X		< 0.01		< 0.01		< 0.01		122	mg/L	lb/day	
c. Color		X	< 5						1	Pt-Co		
d. Fecal Coliform		X	< 2						1	#/100 mL		
e. Fluoride (13694-48-8)	X		0.81	28.5			J 0.73	J 25.5	8	mg/L	lb/day	
f. Nitrate-Nitrite (as N)	X		1.50	52.7			0.47	16.8	14	mg/L	lb/day	

Figure 3 Page V-3 from NPDES Permit Application Form 2C

**PART C:** If you are a primary industry and this outfall contains process wastewater, refer to Table 2c-2 in the instructions to determine which of the GC/MS fractions you must test for. Mark "X" in column 2-a for all such GC/MS fractions that apply to your industry and for ALL toxic metals, cyanides, and total phenols. If you are not required to mark column 2-a (secondary industries, nonprocess wastewater outfalls, and nonrequired GC/MS fractions), mark "X" in column 2-b for each pollutant you know or have reason to believe is present. Mark "X" in column 2-b for each pollutant you believe is absent. If you mark column 2a for any pollutant, you must provide the results of at least one analysis for that pollutant. If you mark column 2b for any pollutant, you must provide the results of at least one analysis for that pollutant if you know or have reason to believe it will be discharged in concentrations of 10 ppb or greater. If you mark column 2b for acrolein, acrylonitrile, 2,4-dinitrophenol, or 2-methyl-4,6-dinitrophenol, you must provide the results of at least one analysis for each of these pollutants which you know or have reason to believe that you discharge in concentrations of 100 ppb or greater. Otherwise, for pollutants for which you mark in column 2b, you must either submit at least one analysis or briefly describe the reasons the pollutant is expected to be discharged. Note that there are 7 pages to this part. Please review each carefully. Complete one table (all 7 pages) for each outfall. See instructions for additional details and requirements.

1. POLLUTANT AND CAS NUMBERS (If available)	2. MARK "X"			3. EFFLUENT						4. UNITS		5. INTAKE (optional)		6. NO. OF ANALYSES	
	a. TEST-ING RE-QUIRED	b. SE-LEVED PRESENT	c. SE-LEVED ABSENT	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (If available)		c. LONG TERM VALUE (If available)		d. NO. OF ANALYSES	a. CONCEN-TRATION	b. MASS	a. LONG TERM AVERAGE VALUE		
				(1) CONCEN-TRATION	(2) MASS	(1) CONCEN-TRATION	(2) MASS	(1) CONCEN-TRATION	(2) MASS				(1) CONCEN-TRATION		(2) MASS
<b>METALS, CYANIDE, AND TOTAL PHENOLS</b>															
1M. Antimony, Total (7440-36-0)	X		X	< 0.05	< 1.502					1	mg/L	lb/day			
2M. Arsenic, Total (7440-38-2)	X	X		0.002	0.070			J 0.001	J 0.043	8	mg/L	lb/day			
3M. Beryllium, Total (7440-41-7)	X		X	< 0.001	< 0.036			< 0.001	< 0.035	6	mg/L	lb/day			
4M. Cadmium, Total (7440-43-8)	X		X	< 0.0010	< 0.036			< 0.0008	< 0.026	8	mg/L	lb/day			
5M. Chromium, Total (7440-47-3)	X	X		0.0004	0.014			J 0.0038	J 0.135	8	mg/L	lb/day			
6M. Copper, Total (7440-50-8)	X	X		0.0074	0.260			J 0.0047	J 0.165	8	mg/L	lb/day			
7M. Lead, Total (7439-92-1)	X	X		0.0138	0.474	0.0083	0.286	0.0022	0.078	125	mg/L	lb/day			
8M. Mercury, Total (7439-97-6)	X	X		1.21	0.000042			0.64	0.000022	3	µg/L	lb/day			
9M. Nickel, Total (7440-02-0)	X	X		0.0024	0.084			J 0.0043	J 0.150	8	mg/L	lb/day			
10M. Selenium, Total (7782-49-2)	X		X	< 0.005	< 0.178			< 0.004	< 0.148	8	mg/L	lb/day			
11M. Silver, Total (7440-22-4)	X		X	< 0.01	< 0.300					1	mg/L	lb/day			
12M. Thallium, Total (7440-28-0)	X		X	< 0.02	< 0.601					1	mg/L	lb/day			
13M. Zinc, Total (7440-66-6)	X	X		0.186	7.871	0.039	1.457	0.020	0.693	125	mg/L	lb/day			
14M. Cyanide, Total (57-12-6)	X		X	< 0.005	< 0.178					2	mg/L	lb/day			
15M. Phenols, Total	X		X	< 0.005	< 0.178					2	mg/L	lb/day			
<b>DIOXIN</b>															
2,3,7,8-Tetra-chlorodibenzo-P-dioxin (1784-01-6)			X	DESCRIBE RESULTS											

shown in Figure 3, the applicant believed that chromium and mercury would be present but that selenium would be absent. The monitoring data confirmed that assessment.

The sensitivity of the analytical method used in monitoring for permit applications can affect conclusions. For example, mercury was typically not quantifiable below 200 parts per trillion until Analytical Method 1631 became approved for use in 1999. Method 1631 can detect mercury at the 0.5-part-per-trillion level. Some of the larger permit applications reviewed as part of this study were submitted to the agencies in the 1990s. Mercury would have most likely been measured using an older analytical method. Unless the more sensitive method is used, mercury may be reported as “below detection” and, therefore, erroneously confirm a conclusion that it is not present.

### 3.1.3 Data from Issued Permits

NPDES permits may place limits on the concentration of a pollutant (mg/L), on the mass loading of a pollutant (lb/day), or on both. The permits may contain average limits, maximum limits, or both. In some cases, the permit does not establish limits but requires monitoring for various parameters. The permits also indicate the type and frequency of sampling that must be done. The results of the monitoring must be submitted to the permitting agency monthly or on some other specified frequency.

Figure 4 shows a final limitations page from the 2007 BP-Whiting NPDES permit. The final outfall, after the process modifications and installation of a diffuser structure on the discharge pipe, is numbered 005. The first column indicates the parameters with restrictions for this outfall. The next three columns show the mass loading limits (most with units of lb/day). The next set of three columns indicates limits or monitoring requirements in concentration units (mg/L, except for mercury, which is in ng/L). The last two columns indicate the required frequency of sampling and the type of sample that the discharger must collect.

For each discharger that underwent a file review as part of Argonne’s data collection efforts, the average and maximum loading limits and concentration limits from the permit were entered into the database. This reflects the legal allowances for that discharger. Most facilities discharged quantities well below their permit limits most of the time.

Some permits had different limits for different months of the year. This was particularly common for ammonia limits at municipal wastewater treatment plants that used biological treatment systems. The water bodies to which the plants discharge have different assimilative capacities depending on the water temperature and the dissolved oxygen in the water column. In those cases, the highest monthly or seasonal limits were used in the study database.

Other permits established more than one set of limits as the facilities modified their operations or changed their wastewater treatment systems. Typically, the permit would have a more lenient set of interim limits and a stricter set of final limits. In those cases, the final limits were used in the study database.

Figure 4 Effluent Limits Page from BP’s 2007 NPDES Permit

DISCHARGE LIMITATIONS OUTFALL 005 [1][3]								
Parameter	Quantity or Loading		Units	Quality or Concentration		Units	Monitoring Measurement Frequency	Requirements Sample Type
	Monthly Average	Daily Maximum		Monthly Average	Daily Maximum			
Flow	Report	Report	MGD	----	----	----	Daily	24-Hr. Total
BOD <sub>5</sub>	4,161	8,164	lbs/day	Report	Report	mg/l	1 x Weekly	24 Hr. Comp.
TSS	4,925	7,723	lbs/day	Report	Report	mg/l	2 x Weekly	24 Hr. Comp.
COD	30,323	58,427	lbs/day	Report	Report	mg/l	1 x Weekly	24 Hr. Comp.
Oil and Grease	1,368	2,600	lbs/day	Report	Report	mg/l	1 x Weekly	Grab
Phenolics (4AAP)	20.33	73.01	lbs/day	Report	Report	mg/l	1 x Weekly	24 Hr. Comp.
Phosphorus	Report	Report	lbs/day	Report	1.0	mg/l	1 x Weekly	24 Hr. Comp.
Ammonia as N	1,584	3,572	lbs/day	Report	Report	mg/l	5 x Weekly	24 Hr. Comp.
Sulfide	23.1	51.4	lbs/day	Report	Report	mg/l	1 x Weekly	24 Hr. Comp.
Total Chromium [4]	23.9	68.53	lbs/day	Report	Report	mg/l	1 x Weekly	24 Hr. Comp.
Hex. Chromium [5]	2.01	4.48	lbs/day	Report	Report	mg/l	1 x Weekly	Grab
Total Vanadium [7]	Report	Report	lbs/day	Report	Report	mg/l	1 x Monthly	24-Hr. Comp.
Interim	50	100	lbs/day	0.28	0.56	mg/l	1 x Monthly	24-Hr. Comp.
Total Mercury [7]	Report	Report	lbs/day	Report	Report	ng/l	2 x Yearly	Grab
Interim	0.00023	0.00057	lbs/day	1.3	3.2	ng/l	6 x Yearly	Grab
Final [6]								
Whole Effluent Toxicity [8]								
Chronic	-	-	-	Report	-	-	TUc	2 x Yearly
pH [2]					Report	s.u.	3 x Weekly	Grab

3.1.4 Data from Discharge Monitoring Reports (DMRs)

Under the NPDES program, all monitoring is conducted by the discharger for the parameters indicated in the permit and at the frequency specified in the permit. Figure 4 shows the types of monitoring that BP will be expected to conduct when the new outfall with a diffuser structure is in place. Dischargers are required to submit monthly DMRs to the permitting agency. The DMRs show the parameters limited in the permit and the facilities’ actual performance.

A sample page from the January 2008 DMR submitted by an industrial facility is shown in Figure 5.<sup>4</sup> The blue boxes were added to mask the identity of the company (not BP). For each parameter, the shaded row shows the permit requirement, and the row with a white background shows the sample result for that month. In this example, the TSS and ammonia values reported on the DMR were well below the permitted limits.

With limited exceptions, electronic reporting for DMRs is not currently in practice. This means that the agencies receive hundreds of printed DMRs each month that must be reviewed and filed. Programs are in place to manually enter the data from each DMR into online databases set up by EPA.

<sup>4</sup> The image comes from a second-hand scanned copy of the DMR and is not available at high resolution. It is included here to show an example of how actual data are filled in on the form. Readers can see a blank DMR form on EPA’s website at: <http://www.epa.gov/npdes/pubs/dmr.pdf>.

Figure 5 Page from an Actual DMR

PERMITTEE NAME/ADDRESS (include Facility Name, location # if Permit)		NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) DISCHARGE MONITORING REPORT (DMR)								Form Approved CMI No. 2040-0004 Approval Expires 5-31-08				
NAME ADDRESS		PERMIT NUMBER		DISCHARGE NUMBER						NOTE: Read instructions before completing this form.				
FACILITY LOCATION		MONITORING PERIOD												
ATTN:		FROM	MO	DAY	YEAR	TO	MO	DAY	YEAR					
PARAMETER	X Sample Measurement Permit Requirement	QUANTITY OR LOADING			QUANTITY OR CONCENTRATION					NO. OF ANALYSIS	FREQUENCY	SAMPLE TYPE		
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS						
PH					5.5					( 12 )	0	3/7	GRAB	
00400 R 0 0 SEE COMMENTS BELOW					8.0 MINIMUM				8.0 MAXIMUM				THREE/ WEEK	GRAB
SOLIDS, TOTAL SUSPENDED		45	57	( 25 )		0			0	( 15 )	0	9/31	24HC	
00530 R 0 0 SEE COMMENTS BELOW		1135 MO AVG	2184 DAILY MAX	LBS/DY		REPORT MO AVG			REPORT DAILY MAX				TWICE/ WEEK	COMP24
OIL AND GREASE			< 17.1	( 25 )					< 2.0	( 15 )	0	10/31	GRAB-3	
00555 R 0 0 SEE COMMENTS BELOW			31.0 DAILY MAX	LBS/DY					REPORT DAILY MAX				TEN/ MONTH	GRAB-3
NITROGEN, AMMONIA TOTAL (AS N)		0.43	2.62	( 25 )		70			410	( 25 )	0	10/31	24HC	
00610 R 0 0 SEE COMMENTS BELOW		703.0 MO AVG	990.0 DAILY MAX	LBS/DY		REPORT MO AVG			REPORT DAILY MAX				TEN/ MONTH	COMP24
CYANIDE, WEAK ACID DISSOCIABLE		0.10	0.22	( 25 )		13.4			25.0	( 25 )	0	10/31	24HC	
00716 R 0 0 SEE COMMENTS BELOW		REPORT MO AVG	REPORT DAILY MAX	LBS/DY		REPORT MO AVG			REPORT DAILY MAX				TEN/ MONTH	GRAB-3
CYANIDE, TOTAL (AS CN)		1.80	3.23	( 25 )		257			470	( 25 )	0	10/31	24HC	
00720 R 0 0 SEE COMMENTS BELOW		44.6 MO AVG	81.0 DAILY MAX	LBS/DY		REPORT MO AVG			REPORT DAILY MAX				TEN/ MONTH	GRAB-3
IRON		1.53	1.97	( 25 )		187			230	( 25 )	0	3/31	24HC	
TOTAL RECOVERABLE		REPORT MO AVG	REPORT DAILY MAX	LBS/DY		REPORT MO AVG			REPORT DAILY MAX				THREE/ MONTH	COMP24
00980 R 0 0 SEE COMMENTS BELOW														
NAME/TITLE PRINCIPAL EXECUTIVE OFFICER		I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.								SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT				
TYPED OR PRINTED										Area Code Number MO DAY YEAR				
COMMENT AND EXPLANATION OF ANY VIOLATIONS (Reference all attachments here)														
Highlighted Monthly Average values are the result of LOQ based calculations.														

### 3.1.4.1 Permit Compliance System

EPA has operated the online Permit Compliance System (PCS) database of NPDES information for many years.<sup>5</sup> Much of the DMR information is entered in PCS, where it can be retrieved. However, due to output limitations, PCS is of limited use for compiling summary statistics. Illinois, Michigan, and Wisconsin use PCS.

### 3.1.4.2 Enforcement and Compliance History Online

Some states (including Indiana) have moved their NPDES data onto a newer online data system called Enforcement and Compliance History Online (ECHO).<sup>6</sup> During 2005, Indiana stopped entering data into PCS and began entering data into ECHO. ECHO provides more features and

<sup>5</sup> The URL for PCS is [http://www.epa.gov/enviro/html/pcs/pcs\\_query\\_java.html](http://www.epa.gov/enviro/html/pcs/pcs_query_java.html), visited on April 10, 2008.

<sup>6</sup> The URL for ECHO is [http://www.epa-echo.gov/echo/compliance\\_report\\_water\\_icp.html](http://www.epa-echo.gov/echo/compliance_report_water_icp.html), visited on April 10, 2008.

allows users to display and export monitoring data much more easily than does PCS. All DMR data for Indiana used in the study database were extracted from ECHO. Where sufficient monthly samples were available, all 2007 data were used. In most cases, either 9 or 12 monthly sample values could be found in ECHO. For other parameters that were reported at a frequency of less than monthly, as many data values as possible (up to the latest 9 values) were used to calculate an average and to identify a maximum value.

The emphasis of the study is to identify the quantity of target pollutants discharged by individual dischargers. Therefore, where mass loading data were available from ECHO, only those data were entered into the database. Where mass loading data were not available, concentration data and flow data were entered into the database. Mass loading was calculated by multiplying concentration by flow by a conversion factor.

### **3.2 Data from State Agencies**

On November 30, 2007, Argonne wrote to representatives of the NPDES programs at the Illinois Environmental Protection Agency (IEPA), Indiana Department of Environmental Management (IDEM), and Michigan Department of Environmental Quality (MDEQ). Argonne requested information about those facilities holding NPDES permits that discharge to Lake Michigan or within the Lake Michigan drainage area. Within that subset of permits, Argonne requested information on those facilities that might discharge more than small amounts of the following pollutants:

- TSS,
- ammonia,
- total nitrogen,
- total chromium,
- hexavalent chromium,
- mercury,
- vanadium, and
- selenium.

Although total nitrogen is not part of the target pollutant list, Argonne initially asked for data on total nitrogen, anticipating that such data might be available for facilities that did not have any ammonia data. Argonne felt that it may be possible to develop a relationship between ammonia concentration and total nitrogen concentration, and thereby extrapolate ammonia concentrations for facilities without that data. After examining numerous applications, permits, and DMRs, Argonne recognized that very minimal total nitrogen data were available. As a result, total nitrogen data are not included in the final database for point source discharges.

#### **3.2.1 Evaluation of State Data**

Each state replied with different levels of information. Each state provided a master list containing the names of all facilities that discharge to the Lake Michigan drainage. However, the specific data elements on those master lists differed among states, necessitating slightly different approaches to evaluating the master lists. Different filtering mechanisms were used to remove

those facilities that were unlikely to discharge levels of the target pollutants that would make significant contributions to the database. The threshold for “significant” quantities was loosely defined as 25 lb/day for TSS, 1 lb/day for ammonia, and any detectable amount for the metals. The types of information received from each state, the filtering approaches used to develop final lists of facilities, and the methods used to obtain specific data are described in the following sections.

### **3.2.2 Illinois**

#### **3.2.2.1 Sources of Information**

The Division of Water Pollution Control, IEPA, provided a list of 12 facilities that discharge into the Lake Michigan drainage area. Illinois has only a short stretch of frontage on Lake Michigan. About 1900, the Chicago Sanitary and Ship Canal was constructed to connect the south branch of the Chicago River to the Des Plaines River. This redirected the drainage from much of the greater Chicago region away from Lake Michigan so that it now flows into the Mississippi River watershed, except under extreme rainfall events. As a result of these two factors, very few discharges currently flow into or toward the lake. The 12 facilities are, for the most part, either industrial facilities with minimal current operations, or discharges that are not likely to contain any significant quantities of the pollutants listed above.

#### **3.2.2.2 First Filter—Elimination of Closed and Insignificant Discharges by Individual PCS Evaluation**

Six of the 12 facilities were found to be either closed or to have discharges that did not contribute significant quantities of the target pollutants. These facilities were eliminated from further study.

#### **3.2.2.3 Final List and Visit to IEPA**

An Argonne representative visited the IEPA office in Springfield, Illinois, on December 11, 2007, to examine the agency’s NPDES files for the remaining six facilities. Other than a significant TSS load at one facility, the other facilities had minimal discharges of the target pollutants and were not considered in the Illinois database.

### **3.2.3 Indiana**

#### **3.2.3.1 Sources of Information**

The Permitting Branch of IDEM’s Office of Water Quality sent Argonne a list of NPDES permitted facilities discharging into Lake Michigan or its tributaries. The full list contained 187 permitted facilities and served as the starting point. Of these, 32 facilities are ranked by EPA as major facilities. Although filtering methods excluded some facilities from detailed evaluation, all of the major facilities were individually evaluated by file review.

Indiana has only a short stretch of frontage on Lake Michigan. Most of the facilities in northwestern Indiana discharge directly into the lake or into tributaries that enter the Indiana

portion of Lake Michigan. Some of the facilities near the Illinois border discharge into water bodies that flow west to the Chicago Sanitary and Ship Canal, which in turn flows into the Mississippi River watershed. However, in other portions of northern Indiana, most facilities discharge into water bodies that flow northward into the St. Joseph River system. The St. Joseph River continues into Michigan, where it enters Lake Michigan within the Phase I boundaries.

### 3.2.3.2 First Filter—Permit Type

The full list contains 45 facilities that are covered by NPDES general permits. To be covered under a general permit, facilities submit a rather brief Notice of Intent (NOI) form rather than a detailed permit application. The NOIs rarely contain detailed analytical information about pollutants in the effluent.

Fifteen of the facilities are covered by a general permit for groundwater petroleum remediation systems (generally these are groundwater cleanup efforts at gas stations). The permits have limits only on benzene and pH. Nine other facilities operate under a general permit for noncontact cooling water. That permit requires monitoring only for oil and grease, temperature, and pH. The permit files are unlikely to contain any information on the target pollutants. One facility operates under a general permit for hydrostatic pressure testing. Hydrostatic testing is typically a one-time or infrequent event at any given location. There is no ongoing discharge at the location. Therefore, these 25 facilities were dropped from further study.

Three other facilities discharge under the provisions of a general permit for sand and gravel operations. This permit requires monitoring for TSS. An additional 17 facilities discharge under the provisions of a general permit for discharges associated with petroleum products terminals. That general permit establishes limits on three pollutants and includes monitoring requirements for six other pollutants, including TSS and ammonia. Because these permits have monitoring for one or more of the target pollutants, these facilities remained on the list for further study.

### 3.2.3.3 Second Filter—Discharge Flow Volume

After the first filtering, 162 facilities remained on the list. A facility's discharge volume has a direct relationship to the loading of the target pollutants from that facility. The relationship between concentration and loading can be described as:

$$\text{Concentration (mg/L)} \times \text{Flow (MGD)} \times 8.32 = \text{Loading (pounds/day)} \quad \text{Equation (1)}$$

As an example, if a discharge of 0.1 million gallons per day (MGD) has a TSS concentration of 30 mg/L (a common permit effluent limit for TSS), the resulting load of TSS is about 25 lb/day. Compared to larger industrial and municipal facilities that discharge hundreds of pounds per day of TSS, discharges of this magnitude are small and can reasonably be excluded from the analysis.

The list of facilities provided by IDEM includes flow data for some of the facilities. Where flow data values are available, all nonmajor permits that had flow of 0.1 MGD or less were eliminated from further study. Fifty-six facilities were removed from the list by the application of this flow volume filter.

### **3.2.3.4 Third Filter—Individual Evaluation Using ECHO**

Following the second filtering, 106 facilities remained on the list. Each of these facilities was individually evaluated to determine the pollutants limited by the permit and to review some recent DMR data by using the ECHO online database for environmental data. A total of 41 facilities were removed from the third-filter list. Numerous facilities were removed from the list because of some combination of low discharges of TSS and ammonia. Others were dropped because they had reported no recent discharges, had discharge volumes much lower than had been considered during the second filtering, or were discharging wastewater streams that did not have any effluent limits for the target pollutants. Two facilities on the list do not discharge into the Lake Michigan drainage area but rather the Lake Erie drainage area and were, therefore, removed from further study.

### **3.2.3.5 Final List, Visit to IDEM, and Revised Final List**

An Argonne representative visited the IDEM offices in Indianapolis on March 24 and 25, 2008. He reviewed IDEM files for the 65 facilities on the final list and determined that 18 of the facilities did not contribute significantly to the loading of target pollutants. These facilities were eliminated, leaving a revised final list of 47 facilities.

For the remaining facilities, Argonne obtained permit limits, as applicable, for the target pollutants. Where NPDES permit applications were available that included effluent concentrations or loadings for the target pollutants, that information was entered into an Indiana database. The DMR concentration and loading data for all facilities were obtained from ECHO.

## **3.2.4 Description of Michigan Data**

### **3.2.4.1 Sources of Information**

The MDEQ's Water Bureau provided data on all of the permitted facilities that discharge into the Lake Michigan drainage area (1,744 municipal, industrial, stormwater, and other discharges). The data included separate pollutant-specific lists of permits issued by the MDEQ that had limits or monitoring requirements for any of the target pollutants.

### **3.2.4.2 First Filter—County**

For Phase I purposes, Argonne evaluated all permitted facilities in the four counties in the southwestern part of the state (Berrien, Cass, St. Joseph, and Van Buren). Kalamazoo County and the city of Kalamazoo are also located in that part of the state, but most of the water from those jurisdictions drains to the Kalamazoo River, which flows north and west, before entering Lake Michigan well north of the Phase I boundary. By using this filtering method, some facilities located near the borders of the included counties may be omitted. However, Phase I will still provide an interim approximation, and any facilities omitted here will be captured in the Phase II study. The list of permitted facilities located in the four counties in the southwestern corner of Michigan contains 234 facilities.

### 3.2.4.3 Second Filter—Facility and Permit Type

The facilities on the first-filter list can be categorized as follows:

- industrial or commercial facilities (77 total, 4 major facilities),
- sanitary wastewater facilities (37 total, 9 major facilities),
- municipal separate storm sewers (19 total, no major facilities),
- industrial stormwater (99 total, no major facilities), and
- concentrated animal feeding operations (2 total, no major facilities).

The MDEQ has issued NPDES general permits for the last three categories listed above. None of these general permits require monitoring for any of the target pollutants. In the absence of application or permit data, no useful data for the inventory can be derived from these permits. Therefore, the 120 municipal separate storm sewers, industrial stormwater facilities, and concentrated animal feeding operations were dropped from further study.

Within the industrial or commercial category is a subset of 23 permits that operate under another MDEQ general permit (for noncontact cooling water). That general permit requires monitoring, but only for total residual chlorine and temperature. The permit files are unlikely to contain any information on the target pollutants. Therefore, these facilities are dropped from further study.

### 3.2.4.4 Third Filter—Likelihood of Presence of Target Pollutants

After the second filtering, 91 facilities remained. Thirteen of the facilities are categorized by EPA as major facilities. All of these facilities are included on the final list for detailed evaluation. For the other 78 nonmajor facilities, the pollutant-specific spreadsheets provided by the MDEQ were examined to see if the facility was listed on any of the spreadsheets. If a facility appeared on any of the spreadsheets, it was included it on the working list for additional evaluation.

Using this filtering scheme, 53 facilities remained on the third-filter list. In order of frequency of listing: 50 Phase I regional facilities were on the TSS list, 31 were on the ammonia list, 12 were on the mercury list, 2 on the hexavalent chromium list, and 1 was on the selenium list. No facilities from the second-filter list were found on the total chromium and vanadium lists. All of the major facilities on the second-filter list were listed on at least one of the pollutant lists and were, therefore, included for further study.

### 3.2.4.5 Fourth Filter—Individual Evaluation Using PCS

All 53 facilities on the third-filter list were reviewed by evaluating the online NPDES data maintained by the MDEQ and EPA's PCS resources. Twenty-one of the facilities were dropped following this review because they had flows lower than 0.1 MGD or TSS, ammonia, or chromium levels below the "significant" threshold.

Several facilities operate under a general permit for water treatment plant discharges. The general permits require the operators to collect effluent data but not to submit it until requested

by the MDEQ. There are no readily accessible data to review for these discharges, so they were excluded from further study. Two other facilities operate under a general permit for hydrostatic pressure testing. Hydrostatic testing is typically a one-time event at any given location. There is no ongoing discharge at the locations. A few others had no recent discharge. These facilities were also dropped from further study. The final list contains 32 facilities.

#### **3.2.4.6 Final List and Visit to MDEQ**

An Argonne representative visited the MDEQ offices in Lansing on March 26, 2008, to review permit files for 32 facilities. He extracted permit and application data for each facility and entered it into a Michigan database. Before the office visit, MDEQ had sent Argonne a spreadsheet containing all of the DMR data for the 32 facilities on the final list. Following the office visit, Argonne extracted the DMR data from the Michigan database from that spreadsheet.

### **3.3 Data Analysis and Interpretation Issues**

#### **3.3.1 Data Values below Detection Level**

Most of the data values reported for TSS and ammonia were well above the detection level of the approved analytical tests. On the other hand, many of the results for the metals analyses were reported as less than the detection level (<DL) of the method used. Values reported as <DL can be treated in several ways:

- Set the value equal to the full value of the DL, accepting that this is an overestimate;
- Set the value at zero, accepting that this may be an underestimate; or
- Set the value at half of the DL, as a compromise.

While examining data from applications and DMRs, Argonne handled data reported as <DL in the following way: when a single data value was shown as <DL, such as on an application form, Argonne considered it to be zero and did not include it in the database. When all of the 2007 monthly entries were <DL, as was found in some of the DMR results, Argonne treated these as zero, and did not include an entry in the database. When a set of monthly data values for 2007 DMRs included some data points with discrete values above the DL but others were reported as <DL, the values listed as <DL were set equal to the DL for the purposes of calculating an average.

#### **3.3.2 Confusion about Units**

Although metric concentration units (mg/L, µg/L, and ng/L) are readily interchangeable, errors in transcription or retyping may occur. The concentrations of TSS and ammonia are typically reported in units of mg/L. Chromium, selenium, and vanadium can be reported in either mg/L or µg/L. Mercury can be reported in either µg/L or ng/L.

During Argonne's review of permit files and DMRs, some data points appeared to be mistaken-unit values. Values that were orders of magnitude out of line with other comparable data points were not included in the calculations.

### 3.4 Toxics Release Inventory

Although the NPDES program provides the most detailed information about discharges to Lake Michigan and its tributaries, Argonne also examined a completely separate national program known as the Toxics Release Inventory (TRI). Begun in 1988 through the Emergency Planning and Community Right-to-Know Act (EPCRA), the TRI contains information on releases of nearly 650 chemicals and chemical categories from industries including manufacturing, metal and coal mining, electric utilities, and commercial hazardous waste treatment, among others. Facilities must report release and other waste management information if they:

- Have 10 or more full-time employees or the equivalent;
- Are in a covered North American Industry Classification System (NAICS) code; and
- Exceed any one threshold for manufacturing (including importing), processing, or otherwise using a toxic chemical listed in 40 CFR Section 372.65. Additional information can be found in 40 CFR Section 372.22.

Each year, industries within the scope of the TRI must report releases of the listed chemicals to different media, such as air, surface water, ground water via underground injection, land via land treatment, impoundments, or other mechanisms. EPA makes the TRI data readily available through its TRI Explorer tool.<sup>7</sup> Users can extract data from different geographic regions, for subsets of the chemicals, or for different industry sectors.

#### 3.4.1 Limitations of TRI Data

TRI has several limitations that restrict the amount of information that can be collected for this study. First, TRI is limited to toxic chemicals. Therefore TSS data cannot be derived from TRI. Second, TRI does not contain releases of the target pollutants from all facilities—just those from facilities that exceed a size threshold. Third, TRI does not provide information on releases from municipal wastewater treatment plants either.

#### 3.4.2 TRI Data Collection

In spite of its limitations, TRI can serve as a secondary check for large dischargers of the target pollutants. If the reported TRI loadings are considerably higher than the NPDES loadings for the same pollutants, additional evaluation can resolve the discrepancy.

For the purposes of this study, Argonne extracted data on all chemical releases to surface water reported for each of the counties in Illinois, Indiana, and Michigan that contribute discharges to the Lake Michigan drainage area within the Phase I area. This included the following counties:

- Illinois (Cook and Lake);
- Indiana (Elkhart, Kosciusko, LaGrange, Lake, LaPorte, Noble, Porter, St. Joseph, and Steuben);

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<sup>7</sup> The URL is <http://www.epa.gov/triexplorer/facility.htm>, visited April 3, 2008.

- Michigan (Berrien, Cass, St. Joseph, and Van Buren).

The data are reported as total pounds released per year. The TRI chemicals that are relevant to the study's target pollutant list are:

- ammonia,
- chromium,
- chromium compounds,
- mercury,
- mercury compounds,
- selenium,
- selenium compounds,
- vanadium, and
- vanadium compounds.

The results from the individual county outputs were combined into a single list. They are discussed in Section 4.4.

## Chapter 4 Point Source Results

For the purposes of this analysis, dischargers are identified as either industrial or municipal and are assigned a number (e.g., IND-01 or MUN-13). The results of the loadings can be compiled by state, by municipal sector vs. industrial sector, and for the entire Phase I area.

Table 1 shows the numbers of facilities included in the final Phase I study database. Indiana has 59% of the facilities, and Michigan has 40%. About three quarters of the facilities overall are municipal dischargers.

**Table 1 Distribution of Facilities in the Final Database**

State	No. Industrial Dischargers	No. Municipal Dischargers	Total
Illinois	1	0	1
Indiana	15	32	47
Michigan	5	27	32
Total	21	59	80

The most complete and current set of data comes from the DMRs. The loadings resulting from the DMRs are presented first. These are followed by a review of the permit limits and the application data. In the final section, the TRI data are presented.

### 4.1 DMR Data

Table 2 shows the average and daily maximum loadings for the facilities in the database. For each of the target pollutants, different numbers of facilities reported DMR data as shown below:

- TSS—79 facilities,
- ammonia—64 facilities,
- total chromium—17 facilities,
- hexavalent chromium—3 facilities,
- mercury—30 facilities,
- vanadium—1 facility, and
- selenium—3 facilities.

#### 4.1.1 TSS Results

The TSS results range from less than 5 lb/day to a maximum of more than 580,000 lb/day. The highest value is many times higher than the next highest value and, therefore, it strongly influences the overall average and maximum TSS loads.

The DMRs from 2005–2007 were reexamined for the typical TSS discharge values. The very high value was reported in October 2007.



Table 2 (Cont.)

Facility ID	TSS avg lb/day	TSS max lb/day	NH <sub>3</sub> avg lb/day	NH <sub>3</sub> max lb/day	Total Cr avg lb/day	Total Cr max lb/day	Cr <sup>+6</sup> avg lb/day	Cr <sup>+6</sup> max lb/day	Hg avg lb/day	Hg max lb/day	V avg lb/day	V max lb/day	Se avg lb/day	Se max lb/day
MUN-08	74	163	26.0	121.1					0.000040	0.000400				
MUN-09	29	52	10.3	28.7										
MUN-10	127	289	6.0	41.0					0.000059	0.000091				
MUN-11	26	47	3.5	3.9										
MUN-12	23	23	0.0	0.0										
MUN-13	6	14	0.6	8.1										
MUN-14	46	141	13.0	25.0					0.000072	0.000178				
MUN-15	314	389	80.0	248.8										
MUN-16	56	172	4.5	9.7					0.000017	0.000047				
MUN-17	311	691	3.8	104.0	0.16	0.46			0.000190	0.000310				
MUN-18	649	1,573	19.0	50.0		2.80			0.000500	0.000985				
MUN-19	3	20	0.7	4.4	0.02	0.06								
MUN-20	25	348	27.0	101.0					0.000009	0.000038				
MUN-21	29	52	1.1	1.3										
MUN-22	2,702	8,395	332.0	2169.0	1.21	1.36			0.003275	0.006310				
MUN-23	329	983	35.0	260.0	0.14	0.18			0.000214	0.000314				
MUN-24	338	14,482	109.0	1049.0	0.34	0.40			0.000800	0.002000				
MUN-25	20	41							0.000010	0.000020				
MUN-26	116	320	15.0	146.0	0.12	0.12			0.002000	0.002000				
MUN-27	8	42	4.5	0.3										
MUN-28	23	87	0.3	1.2										
MUN-29	50	82	20.4	43.7										
MUN-30	41	71	44.0	95.0	0.03	0.07			0.000015	0.000020				
MUN-31	83	146	24.7	53.9										
MUN-32	12	18	4.2	7.1										
MUN-33	42	245	1.1	14.2										
MUN-34	185	368	9.0	40.0	0.25	0.33			0.000094	0.000247				
MUN-35	17	56	2.0	13.0					0.000496	0.003802				
MUN-36	437	1,197	156.0	521.0		1.20	0.40	0.80						
MUN-37	62	153	5.3	35.0					0.002252	0.019888				

Table 2 (Cont.)

Facility ID	TSS avg lb/day	TSS max lb/day	NH <sub>3</sub> avg lb/day	NH <sub>3</sub> max lb/day	Total Cr avg lb/day	Total Cr max lb/day	Cr <sup>+6</sup> avg lb/day	Cr <sup>+6</sup> max lb/day	Hg avg lb/day	Hg max lb/day	V avg lb/day	V max lb/day	Se avg lb/day	Se max lb/day
MUN-38														
MUN-39	12	30	0.8	5.0										
MUN-40	145	301							0.000030	0.000070				
MUN-41	60	102	5.1	6.9					0.000038	0.000054				
MUN-42	63	207	3.7	11.3					0.000010	0.000040				
MUN-43	10	15	1.2	2.7										
MUN-44	129	657	5.0	30.0										
MUN-45	4	8	16.0	40.0										
MUN-46	14	32	2.0	25.0										
MUN-47	1,816	3,422	95.0	988.0	2.30	3.90								
MUN-48	40	381	4.0	49.0					0.000026	0.000060				
MUN-49	113	399	34.0	50.0					0.000050	0.000100				
MUN-50	42	68	13.0	40.0						0.000010				
MUN-51	35	92	0.8	14.0					0.000006	0.000011				
MUN-52	64	261	4.6	6.9										
MUN-53	110	304	66.2	188.4										
MUN-54	5	9	1.7	3.5										
MUN-55	10	98	1.2	28.0										
MUN-56	209	1,349	8.0	109.0	0.04	0.06			0.000090	0.000875				
MUN-57	229	468	6.8	14.2										
MUN-58	33	63												
MUN-59	18	55	2.3	20.5										
<b>Total - Municipal</b>	<b>10,207</b>	<b>40,950</b>	<b>1,332.1</b>	<b>7,047.0</b>	<b>4.60</b>	<b>10.94</b>	<b>0.40</b>	<b>0.80</b>	<b>0.010751</b>	<b>0.038646</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>	<b>0.000</b>
<b>Total - All facilities</b>	<b>57,376<sup>a</sup></b>	<b>683,953<sup>a</sup></b>	<b>2,245</b>	<b>10,406</b>	<b>11.79</b>	<b>51.34</b>	<b>1.79</b>	<b>2.53</b>	<b>0.024321</b>	<b>0.068566</b>	<b>0.000</b>	<b>0.117</b>	<b>2.763</b>	<b>5.210</b>

<sup>a</sup> The TSS loadings are skewed by one unusually high monthly value. When that high value is removed and replaced by the next highest monthly value, the overall total for TSS changes to 43,688 lb/day average and 235,348 lb/day maximum.

This value is far higher than any other data value reported from 2005–2007. The next highest data value during 2007 was 86,366 lb/day, while all other data values were considerably lower. Argonne contacted the state regulatory agency to confirm the validity of the high value. The agency contact person verified that the data value appeared to be correct.

The single large value affects the overall Phase I totals as well. The total TSS values, derived by adding the average and monthly maximum TSS values for all included discharges, for the entire Phase I study area are: 57,376 lb/day average and 683,953 lb/day maximum. If the single highest value is excluded from the data set, the total TSS loadings decrease to 43,688 lb/day average and 235,348 lb/day maximum.

Table 3 shows the distribution of TSS loads. The industrial dischargers make up a large percentage of both the average and maximum loads. Seven of the industrial facilities and two of the municipal facilities discharge an average of more than 1,000 lb/day of TSS. Ten of the industrial facilities and six of the municipal facilities discharge a maximum of more than 1,000 lb/day of TSS.

**Table 3 Distribution of TSS Loads**

	<b>Total TSS from Industrial Dischargers<sup>a</sup></b>	<b>Total TSS from Municipal Dischargers</b>	<b>Total TSS<sup>a</sup></b>
Average (lb/day)	47,169 (33,481)	10,207	57,376 (43,688)
Maximum (lb/day)	643,003 (194,398)	40,950	683,953 (235,348)

<sup>a</sup> The numbers in parentheses represent totals when the highest value is excluded from the data set.

### 4.1.2 Ammonia Results

The ammonia results range from less than 1 lb/day to a maximum of 2,169 lb/day (at MUN-22). Table 4 shows the distribution of ammonia loads. In contrast to the TSS loadings, both the total average and total maximum ammonia loadings (derived similar to the total TSS loads) are higher in the municipal sector. Three of the industrial facilities and three of the municipal facilities discharge an average of more than 100 lb/day of ammonia. Five of the industrial facilities and 12 of the municipal facilities discharge a maximum of more than 100 lb/day of ammonia.

**Table 4 Distribution of Ammonia Loads**

	<b>Total Ammonia from Industrial Dischargers</b>	<b>Total Ammonia from Municipal Dischargers</b>	<b>Total Ammonia</b>
Average (lb/day)	913	1,332	2,245
Maximum (lb/day)	3,359	7,047	10,406

### 4.1.3 Chromium Results

The total chromium results from 17 facilities range from less than 0.1 lb/day to a maximum of 26.2 lb/day (at IND-17). Table 5 shows the distribution of total chromium loads. Both the average and maximum total chromium loadings are higher in the industrial sector. Four of the industrial facilities and two of the municipal facilities discharge an average of more than 1 lb/day of total chromium. Four of the industrial facilities and four of the municipal facilities discharge a maximum of more than 1 lb/day of total chromium.

**Table 5 Distribution of Total Chromium Loads**

	<b>Total Chromium from Industrial Dischargers</b>	<b>Total Chromium from Municipal Dischargers</b>	<b>Total for Total Chromium</b>
Average (lb/day)	7.2	4.6	11.8
Maximum (lb/day)	40.4	10.9	51.3

It is impossible to draw any conclusions for hexavalent chromium with only 3 data values. Two of the values are from industrial facilities, and the third is from a municipal facility. The composite totals are 1.8 lb/day average and 2.5 lb/day maximum. Undoubtedly, both total and hexavalent chromium are present in many other discharges. However, without any data in the DMRs, it is not possible to consider those other contributions in the database. Bar charts were not created for chromium or the other metals because few facilities had data values.

#### 4.1.4 Mercury Results

Many of the mercury data values in the DMRs were reported as <DL. These were treated as equal to zero (see Section 3.3.1). Thus, many facilities had no mercury results entered into the loading database. Mercury results at or above the detection level were available at 30 facilities. They ranged from less than 0.00001 lb/day to a maximum of 0.017 lb/day (IND-16). Table 6 shows the distribution of mercury loads. The average and maximum mercury loadings are similar for the industrial and municipal sectors.

The detection level of different analytical methods for mercury was discussed in Section 3.1.2. The mercury DMR values included in the database were taken primarily from 2007 DMRs with a few data points going back to 2005 and 2006. Therefore, they should have been analyzed using Method 1631, which has a low detection level.

Permits have not required mercury monitoring until recently. As a result, there are relatively few data values available at most facilities with which to calculate averages. Mercury is typically measured at ng/L levels. As noted in Section 3.3.2, many persons who enter data into systems like PCS and ECHO are not accustomed to dealing with ng/L units. Some data in ECHO was clearly entered incorrectly, thus limiting the usefulness of those data values.

**Table 6 Distribution of Mercury Loads**

	<b>Mercury from Industrial Dischargers</b>	<b>Mercury from Municipal Dischargers</b>	<b>Total Mercury</b>
Average (lb/day)	0.01357	0.01075	0.02432
Maximum (lb/day)	0.02992	0.03865	0.06857

#### 4.1.5 Vanadium Results

Only a single vanadium data point was available from the DMRs. It was a maximum of 0.117 lb/day. Vanadium is not commonly limited or monitored in wastewater discharges. It is not possible to draw any conclusions for vanadium from this single data point.

The intention of this study is to catalog and compare discharges of the target pollutants throughout the study area. With only a single vanadium data point, this is not possible. No further analysis can be performed on vanadium discharges for Phase I. As the study moves into Phase II, other vanadium discharges may be identified.

#### 4.1.6 Selenium Results

Only three selenium data points were available from the DMRs. All were at industrial facilities. The composite average was 2.76 lb/day, and the composite maximum was 5.21 lb/day. It is not possible to draw conclusions for selenium from just three data points. As noted for chromium in Section 4.1.3, selenium is undoubtedly present in many other discharges, but unless those

discharges are monitored and the results entered into DMR records, it is impossible to incorporate them into the loading database for selenium.

As stated above for vanadium, no further Phase I analysis can be performed on selenium. As the study moves into Phase II, other selenium discharges may be identified.

#### 4.2 Permit Limit Data

Data compiled from permit limits give another perspective on the total load of target pollutants within the Phase I area. Permit limits represent the upper limit of allowable discharges. The permit limit data are summarized in Table 7. The permit limit data set has fewer values than the DMR data set:

- TSS—55 facilities vs. 79 in DMR data set,
- ammonia—45 facilities vs. 64 in DMR data set,
- total chromium—3 facilities vs. 17 in DMR data set,
- hexavalent chromium—2 facilities vs. 3 in DMR data set,
- mercury—21 facilities vs. 30 in DMR data set,
- vanadium—1 facility vs. 1 in DMR data set, and
- selenium—2 facilities vs. 3 in DMR data set.

DMR data should be available for every permit that has limits for a target pollutant. In addition, some permits do not have limits for the target pollutants but have requirements to monitor for the target pollutants. In those cases, data will be found in the DMR data set but not in the permit limit data set. Other permits include concentration limits but not loading limits for the target pollutants. Loadings were calculated from the DMR concentration data but cannot be accurately estimated for the permit limit data set because permits rarely place a limit on flow.

In spite of the DMR data set having more entries than the permit limit data set, the actual discharges as shown in the DMRs are considerably lower than the permit limits at most facilities. Some facilities have occasional exceedances of their permit limits, but such exceedances rarely happen over an extended period. Most facilities are operated so that treatment systems perform well below the permit limits to allow for some variation in performance. In other cases, when permit limits are set based on manufacturing input data, current production levels may be lower than they were at the time the permit was written.

Table 7 shows the composite permit limit total for each target pollutant as well as the total from the DMR data set. The last line of the table compares the DMR totals to the permit limit totals. In all but 3 cases, the DMR totals are less than or equal to the permit limit totals. The first exception is the maximum TSS load. This can be attributed to the single very high value described in Section 4.1.1. The second exception is the maximum mercury value. There were 21 facilities that had permit limits for mercury. However, 30 facilities reported information in the DMR data set. Presumably those additional 9 facilities had permit monitoring requirements, but not limits, for mercury. The third exception is the average value for selenium. One facility (IND-03) had a relatively high average selenium discharge. The facility is in

Table 7 Summary of Permit Limits Data Set

	TSS avg	TSS max	NH <sub>3</sub> avg	NH <sub>3</sub> max	Total Cr avg	Total Cr max	Cr+6 avg	Cr+6 max	Hg avg	Hg max	V avg	V max	Se avg	Se max
No. industrial facilities with permit limits	11	11	7	7	3	3	2	2	6	6	1	1	2	2
No. municipal facilities with permit limits	44	34	33	38	0	0	0	0	6	14	0	0	0	0
No. total facilities with permit limits	55	55	40	45	3	3	2	0	12	21	1	1	2	2
Total industrial allowed discharge (lb/day)	45,504	113,140	9,326	21,529	75	165	3.1	6.8	0.01722	0.04225	50	100	2.33	5.2
Total municipal allowed discharge (lb/day)	66,113	110,432	5,532	12,995	0	0	0	0	0.01462	0.01057	0	0	0	0
Overall total allowed discharge (lb/day)	111,617	223,572	14,858	34,524	75	165	3.1	6.8	0.03184	0.05282	50	100	2.33	5.2
Total discharge from DMRs (lb/day)	57,376 (43,688) <sup>a</sup>	683,953 (235,348) <sup>a</sup>	2,245	10,406	11.79	51.34	1.79	2.53	0.02432	0.06856	0.000	0.117	2.763	5.210
Ratio of total load from DMRs to total allowed load (%)	51 (39) <sup>a</sup>	306 (105) <sup>a</sup>	15	30	16	31	58	37	76	130	0	0	119	100

<sup>a</sup> One monthly TSS value was very high and skewed the overall TSS loading. The number in parentheses reflects the discharge load when that high value is replaced by the next highest monthly TSS value.

compliance with the effective interim limits of the permit. The final permit limits, which were included in the permit limits database, do not become effective for several years.

Seven industrial facilities and 5 industrial facilities had mercury concentration limits set at the very low levels specified by the Great Lakes water quality requirements (1.3 ng/L average and 3.2 ng/l maximum). An additional nine municipal permits (from a different state) had mercury maximum concentrations limits of either 10 ng/L or 30 ng/L.

### 4.3 Application Data

Data compiled from permit applications can provide information on pollutants that are not limited in the permit or reported through DMRs. Application data for the target pollutants are incomplete for many facilities in the database. For many other facilities, only concentrations were reported in the applications. Where possible, the concentrations were converted to loadings by using a representative flow value. The most recent applications for some of the larger industrial facilities were submitted years ago and may not accurately reflect the current conditions.

The permit limit data are summarized in Table 8. The permit limit data set has fewer values than does the DMR data set for all of the target pollutants except selenium.

- TSS—56 facilities vs. 79 in DMR data set,
- ammonia—41 facilities vs. 64 in DMR data set,
- total chromium—11 facilities vs. 17 in DMR data set,
- hexavalent chromium—0 facilities vs. 3 in DMR data set,
- mercury—15 facilities vs. 30 in DMR data set,
- vanadium—0 facility vs. 1 in DMR data set, and
- selenium—11 facilities vs. 3 in DMR data set.

Table 8 shows the composite application totals for each target pollutant as well as the total from the DMR data set. The last line of the table compares the application totals to the DMR totals. None of the facilities in the database had application data for hexavalent chromium or vanadium. In half of the remaining cases, the DMR totals are less than or equal to the permit limit totals. The reverse is true for the other half of the cases.

Two examples stand out as having much higher application data than the DMR data. The maximum mercury total from the applications is nearly 12 times higher than the DMR data; 99% of the applications total comes from a single facility that does not have any permit limits for mercury (IND-08) and, therefore, would not need to submit any DMR data for mercury.

The maximum total chromium total from the applications is more than 5 times higher than the DMR data. Of the applications total, 58% comes from a facility that does not have any permit limits for total chromium (IND-17) and, therefore, would not need to submit any DMR data for total chromium. An additional 29% of the applications total comes from a second facility (IND-09). This facility does have a permit limit that is comparable to the load reported on the

Table 8 Summary of Application Data Set

	TSS avg	TSS max	NH <sub>3</sub> avg	NH <sub>3</sub> max	Total Cr avg	Total Cr max	Cr+6 avg	Cr+6 max	Hg avg	Hg max	V avg	V max	Se avg	Se max
No. industrial facilities with application data	11	16	8	10	4	7	0	0	3	7	0	0	1	3
No. municipal facilities with application data	14	40	13	31	2	4	0	0	0	8	0	0	2	8
No. total facilities with application data	25	56	21	41	6	11	0	0	3	15	0	0	3	11
Total industrial load from applications (lb/day)	61,958	290,780	1,269	6,940	17.8	258.6	0	0	.00197	.8114	0	0	.11	1.23
Total municipal load from applications (lb/day)	2,856	21,451	401	7,058	3.3	6.16	0	0	0	.00063	0	0	.17	1.48
Overall total load from applications (lb/day)	64,814	312,231	1,670	13,998	21.10	264.76	0	0	0	0.81203	0	0	0.28	2.71
Total discharge from DMRs (lb/day)	57,376 (43,688) <sup>a</sup>	683,953 (235,348) <sup>a</sup>	2,245	10,406	11.79	51.34	1.79	2.53	0.02432	0.06856	0.000	0.117	2.763	5.210
Ratio of total load from applications to total load from DMRs (%)	113 (148) <sup>a</sup>	46 (133) <sup>a</sup>	74	135	179	516	0	0	8	1,184	0	0	10	52

<sup>a</sup> One monthly TSS value was very high and skewed the overall TSS loading. The number in parentheses reflects the discharge load when that high value is replaced by the next highest monthly TSS value.

application. However, that facility reported very low loads of total chromium in its 2007 DMR data.

All three of these facilities are large industrial facilities that submitted permit applications many years ago. The production level of the facilities has declined since the applications were submitted. Actual current levels are likely to be considerably lower than the application data.

#### 4.4 TRI Data

The TRI national database was searched for each of the 15 counties in which the facilities that discharge to the Phase I area are located. Many of the counties had no releases to surface waters of any of the TRI chemicals that correspond to the study's target pollutants. From the other counties, 11 facilities did report TRI data for the relevant chemicals; some reported more than 1 chemical. In all, 20 release entries covering 6 chemicals were found. Table 9 summarizes the TRI data and converts the annual values to daily values to allow comparison to the other data reported in this chapter. As noted previously, only certain industrial facilities must report under TRI. Municipal facilities and those industrial facilities that are outside the scope of TRI reporting need not submit annual TRI reports.

**Table 9 Data from TRI Database**

<b>TRI Chemical</b>	<b>No. Facilities Reporting under TRI</b>	<b>Total TRI Release to Surface Waters (lb/yr)</b>	<b>Average Daily Release to Surface Waters (lb/day)</b>
Ammonia	6	32,343	89
Chromium	1	5	0.01
Chromium compounds	6	3952.3	10.8
Mercury compounds	4	3.046	0.008345
Selenium compounds	1	50	0.137
Vanadium compounds	2	9,706.3	26.593

The values reported for all of the chemicals are consistent with the discharge data found in the NPDES data with one exception: the release of vanadium compounds to surface waters, primarily from a single facility (IND-03), is considerably higher than the data found from the DMR and application sources. Neither of those databases has an entry for vanadium for IND-03. However, the permit limits for IND-03 are higher than the daily TRI release value, suggesting that the facility is compliant with its vanadium limits.

One other complicating factor is the difference in terminology between the NPDES program and the TRI program. The NPDES program measures vanadium as total vanadium in a water sample. The TRI program has separate chemical categories for vanadium and for vanadium compounds. No facilities reported TRI values for vanadium, but two facilities reported TRI values for vanadium compounds. It is not clear what the difference is and whether the percentage of vanadium in the measurement of vanadium compounds is 100%.

## Chapter 5 Nonpoint Source Contributions

Nonpoint source contributions to Lake Michigan are considerably different than the point source contributions described in the previous chapter. First, they are released over wide areas rather than at discrete locations. This makes measurement of the concentrations and loads quite difficult. A second important consideration is the lack of formal regulatory programs that govern and control nonpoint source releases.

### 5.1 Introduction to Nonpoint Source Pollution

Nonpoint source pollution (NSP) generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification. Technically, the term “nonpoint source” means any source of water pollution that does not meet the legal definition of “point source” in Section 502(14) of the Clean Water Act, which is

“ . . . any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.”

The nature and type of NSP varies with the source. Lake Michigan is sensitive to a wide range of pollutants, and major stresses on the Lake include toxic and nutrient pollution (GLC 2007a). Sources of NSP in southern Lake Michigan include runoff of soils and farm chemicals from agricultural lands, waste from cities, discharges from industrial areas, and leachate from disposal sites. The large surface area of the lake makes it vulnerable to direct atmospheric pollutants that fall with the rain, snow, and dust, or exchange as gases in the lake water.

Nonpoint sources are not subject to federal permit requirements, and no federal regulations require data collection on nonpoint source releases. Section 319 of the Clean Water Act requires that states assess NSP problems and causes within the state and adopt and implement management programs to control the NSP. Data on NSP loadings are typically limited to studies of specific regions and pollutants. Some study results can be applied to southern Lake Michigan, but uncertainties and the margins of error associated with these approaches are high relative to those for point source pollutants, which are based on permit and reporting data. While this chapter includes some estimates of NSP loads in southern Lake Michigan, it should primarily be viewed as a source of information on the sources of NSP and the areas (i.e., watersheds) that discharge land- and water-based NSP into the lake. As with point source pollution, this chapter focuses on only a few key target pollutants (TSS, ammonia, nitrogen, and mercury). The remainder of this chapter describes sources of NSP, the watersheds that carry NSP into southern Lake Michigan, and rough estimates of NSP and loadings for key pollutants.

### 5.2 Sources of Nonpoint Source Pollution

The relative contributions of various sources of NSP (e.g., runoff, atmospheric deposition) to a waterway (e.g., southern Lake Michigan) depend on the specific characteristics of the watersheds

and air sheds from which the pollutants come and on the pollutants themselves. For example, major NSP sources threatening the water quality of Lake Michigan include atmospheric deposition and contaminated sediments. Major sources and causes of NSP are pesticides and fertilizer runoff, construction site erosion, urban runoff, hydrologic modification, soil erosion and sedimentation, livestock water, and resource extraction.

### 5.2.1 Runoff

Diffuse runoff is generally treated as NSP, whereas runoff that enters and is discharged from conveyances such as those described in the definition of point source is treated as a point source discharge. Runoff from agricultural practices, sewer overflows, and construction introduce sediments and nutrients into waterways; road runoff introduces salts, hydrocarbons, and metals.

#### 5.2.1.1 Agricultural Runoff

Erosion, nutrient application, and wastewaters from confined animal facilities contribute to agricultural runoff. These sources are described below.

*Erosion.* Soil erosion can be characterized as the transport of particles that are detached by rainfall, flowing water, or wind. Land clearing and tillage make soils susceptible to erosion. Eroded soil is either redeposited in the same field or transported from the field in runoff or by wind. Sediment results from erosion. It is the solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by wind, water, gravity, or ice. Sediment that leaves croplands and enters water bodies becomes an agricultural NSP. The types of erosion associated with agriculture that produce sediment are sheet and rill erosion, ephemeral and classic gully erosion, wind erosion, and streambank erosion. Erosion also results from nonagricultural sources. For Lake Michigan, streambank erosion is considered the excessive loss of land along streams and rivers of the inland part of the Lake Michigan coastal watershed. Shoreline erosion is the loss of beach and other land along the Lake Michigan coastline. The loss of land due to excessive erosion is caused by a combination of factors, including the loss of riparian vegetation and floodplain roughness that protects the soil and dissipates the energy of the rivers, and the increased peak flow discharge in rivers, which increases the erosive power. Shoreline and streambank erosion is a natural process that can have either beneficial or adverse impacts on the creation and maintenance of riparian habitat, but excessive erosion of shorelines and stream banks can increase sediment loads, turbidity, and nutrients.

Sediment that originates from cropland (e.g., corn, soybeans) has a higher pollution potential than sediment that originates from other agricultural land uses. This is because the topsoil of a crop field is usually richer in nutrients and other chemicals—resulting from past fertilizer and pesticide applications, and from nutrient cycling and biological activity. Hay and pasture agricultural land use is in vegetative cover throughout the year and, therefore, not a significant source of erosion. Hay and pasture agricultural land use generally includes land used for recreational horses, perennial grass and legume cover, or year-round vegetative cover, or land enrolled in the Conservation Reserve Program.

*Nutrient Application.* The application of fertilizer to crops—especially food crops such as corn, soybeans, and wheat—is a common and generally necessary production practice to achieve economically viable crop yields. Nitrogen is a major nutrient applied to cropland with the potential to degrade water quality. Fertilizers can be washed from fields or improperly designed storage or disposal sites. Drainage ditches constructed on poorly drained soils enhance the movement of soluble nutrients. Sources and forms of nutrient application to agricultural land include the following:

- Commercial fertilizer in a dry or fluid form;
- manure from animal production facilities including bedding and other wastes added to the manure;
- municipal and industrial treatment plant sludge;
- municipal and industrial treatment plant effluent;
- legumes and crop residues;
- irrigation water;
- wildlife; and
- atmospheric deposition (EPA 2003).

*Wastewater and Runoff from Confined Animal Facilities.* Wastewaters from confined animal facilities often contain nitrogen, sediments, and other pollutants. These pollutants can be released from improper waste management, overapplication of wastes to fields, leaking lagoons, and from flow of lagoon liquids to surface waters due to improper lagoon water management.

### **5.2.1.2 Urban and Suburban Runoff**

The rate and volume of runoff in urban/suburban areas can often be much greater than that from agricultural runoff, resulting in streambank erosion and sediment in surface waters.

Urban and suburban environments produce large amounts of runoff due to the prevalence of building roofs, paved roads, and parking lots, which prevent precipitation from percolating into the ground. These impervious surfaces, combined with sewers and stormwater handling systems, channel large volumes of water into streams after major rain events, which not only contribute pollutants to the stream, but also erode the stream bed, which increases sediment loads.

Pollutants associated with stormwater runoff from impervious surfaces include sediments, nutrients, and metals. The pollutant most associated with runoff from construction sites or land disturbance is sediment, although other pollutants, including nutrients, are also associated with construction activities. Land clearing or excavation can cause soil loss and sedimentation. Runoff also occurs from on-site sewage disposal systems designed and installed for wastewater treatment. Failure of these systems, due to incorrect characterization of waste load allocations or inadequate accounting of limiting soil or geologic features during system design, can result in nonpoint discharges of nitrogen and other pollutants.

Other sources of urban runoff include everyday household activities, landscaping (e.g., the over-application of fertilizers, improper disposal of lawn trimmings), litter and debris, and domestic

pet droppings. Runoff from roads, highways, and bridges contribute nonpoint sources of fertilizers (roadway maintenance) and metals (washed from the pavement).

EPA (2005) provides data on urban stormwater runoff concentrations. These concentrations represent mean or median storm concentrations measured at typical sites and may be greater during individual storms. The mean or median runoff concentrations from stormwater “hotspots” are two to ten times higher. The only one of the target pollutants listed in EPA (2005) is TSS. The mean or median TSS value for urban runoff given is 80 mg/L.

### **5.2.2 Atmospheric Deposition**

Airborne emissions from local and distant sources add pollutant loadings to waters through atmospheric deposition. Atmospheric inputs to water bodies occur through several mechanisms. Pollutants that are released to the air can be deposited directly to the water body by wet deposition (the removal of air pollutants from the air by rain or snow), dry deposition (the removal of aerosol pollutants through eddy diffusion and impaction, large particles through gravitational settling), or by gas exchange (the direct transfer of gaseous pollutants from the air to the water).

The tendency of a specific pollutant to enter a water body through wet deposition, dry deposition, or gas exchange relates to the physical and chemical properties of the pollutant and to current and local meteorology. For example, sources of atmospherically deposited mercury include emissions from industrial and combustion sources, emissions from natural sources (e.g., volcanoes), and re-emission from mercury-contaminated soils and water. Contributing sources can originate in the United States and other countries, and the emissions can be deposited near the sources or they can travel across international borders (EPA 2000a).

Air pollutants can also enter the water body through indirect deposition, which occurs when an air pollutant is deposited to a land area or tributary and is then carried into a water body by other routes, such as stormwater runoff or inflow from tributaries.

The determination of the relative roles of particular contributing sources to specific water bodies requires a variety of monitoring, modeling, and other analytical techniques. Pollutant loading estimates from air deposition suffer from significant uncertainties due to errors inherent in sampling methodologies, the assumptions about a specific chemical’s behavior that are used to develop deposition estimates, and spatial and temporal limitations with monitoring networks.

### **5.2.3 Hydromodification**

Hydromodification is the alteration of the natural flow of water through a landscape to improve flood control, navigation, or drainage, or to reduce channel migration. Hydromodification can include straightening, widening, deepening, or relocating existing stream channels. It can also involve dam construction, excavation of borrow pits or canals, building of levees, underwater mining, streambed and shoreline modification, and other practices that change the depth, width, or location of waterways. Channel modification often produces unstable conditions that cause streambank erosion and deposition of sediment in the streambed.

### 5.2.4 Marina and Recreational Boating Nonpoint Pollution

Sources of nonpoint pollution from these facilities include sewage waste disposal (on land and around the marinas and from vessels themselves) and improper boat operation, which can destroy shallow-water habitat and resuspend bottom sediment and pollutants.

### 5.2.5 Sediments

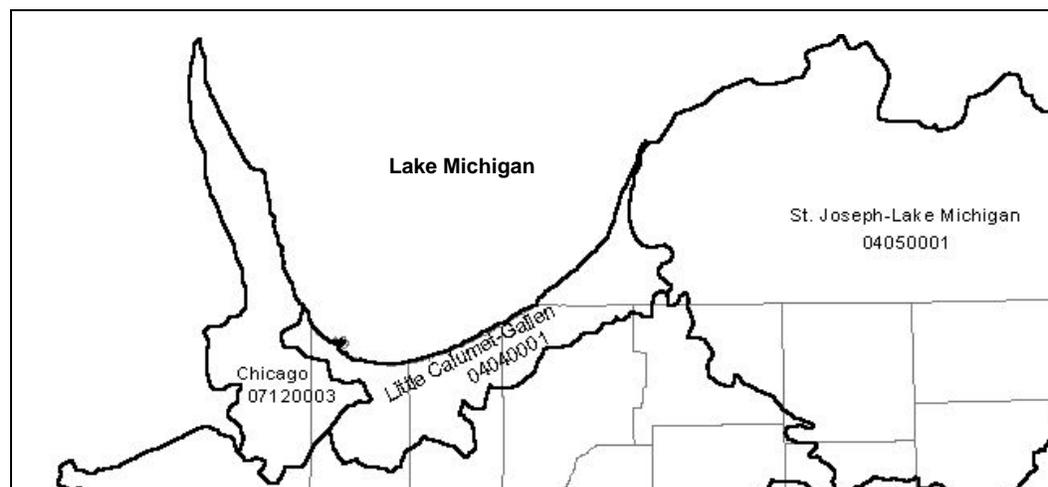
Contaminated river sediments also contribute to NSP. For example, it is estimated that the Grand Calumet River and the Indiana Harbor and Ship Canal contain between four and five million cubic yards of contaminated sediments. Of these sediments, approximately 150,000 cubic yards migrate into the southern end of Lake Michigan annually (Indiana DNR 2005).

## 5.3 Watersheds of Southern Lake Michigan

A watershed is the land area that drains water and sediments (runoff) into a stream, river, lake, estuary, or coastal zone. Large watersheds—for example, the Lake Michigan Basin—are composed of several smaller watersheds, each of which contributes runoff to different locations that ultimately combine at a common delivery point. The size of the watershed, its topography, and how the land within the watershed is used determine the sources, amounts, and types of NSP that will enter the receiving body, in this case, southern Lake Michigan.

Watershed boundaries are defined by the topographic features that dictate natural drainage patterns within an area. The U.S. Geological Survey (USGS) uses a hierarchical classification of hydrologic drainage basins to define watersheds of the United States. River basins are the highest level (classified according to 4-digit accounting units), followed by sub-basins (8-digit cataloging units), and hydrologic units (14-digit units), which is the smallest administrative unit. Figure 6 shows the 8-digit watersheds that border southern Lake Michigan: Chicago (07120003), Calumet-Galien (04040001), and St. Joseph-Lake Michigan (04050001).

**Figure 6 Watersheds Bordering Southern Lake Michigan**



Source: Indiana DNR 2005

### 5.3.1 Chicago Watershed

Although it borders southern Lake Michigan, the Chicago Watershed generally drains away from the lake. This is because the Chicago River, the Des Plaines River, the Chicago Sanitary and Ship Canal, and the Calumet River System have been engineered to drain away from Lake Michigan during most wet-weather conditions. However, during certain heavy rainfall events, the gates at the waterway-controlling works that separate the Chicago area waters and Lake Michigan are opened to prevent local flooding. During these river reversals, river water that contains runoff from stormwater outflows is discharged to the southern part of the lake. River reversals can also include discharges from sanitary sewer overflows, stormwater runoff, agricultural runoff, and other NSP sources. The most recent reversal occurred on August 23–24, 2007, during which 224 million gallons flowed to Lake Michigan. Reversals do not occur frequently; the previous reversal occurred in 2002, when 1.7 billion gallons of river water affected by combined sewer overflow<sup>8</sup> discharges were diverted to Lake Michigan (EPA 2007). Table 10 shows the history of river reversals since 1985.

Although most of the river flow of the Chicago Basin does not reach Lake Michigan, other nonpoint sources from some small tributaries and other direct runoff may flow into the Lake. This is recognized in the description of the boundaries of the Illinois coastal zone. The Illinois coastal zone is roughly 100 square miles, consisting of 85 square miles within the present-day Lake Michigan watershed (which accounts for the majority of the river flow being diverted from the Lake) and 25 square miles of inland waters. Included in these boundaries are the watersheds of the streams that drain the area and drain into Lake Michigan. The coastal zone boundary also includes the ravines of the North Shore municipalities and the lakeshore parks, lakes, streams, and wetlands in southeastern Chicago that have a hydrologic connection to Lake Michigan. Figure 7 depicts the boundaries of the Illinois coastal zone, which can be considered (like the Little Calumet-Galien and St. Joseph watersheds) to provide NSP into Lake Michigan.

### 5.3.2 Calumet-Galien Watershed

The Coastal Zone Act Reauthorization Amendments of 1990, Section 6217, requires that states and territories with approved coastal management programs develop a coastal nonpoint pollution control program to address water quality impairment of coastal waters. For Indiana, the term “coastal waters” refers to the lakes, rivers, and wetlands that drain into Lake Michigan. In meeting the Act’s requirements, the IDNR, Indiana Department of Environmental Management, and other partner organizations have developed a Nonpoint Pollution Control Plan (NPCP) for the Indiana lands that drain into Lake Michigan. The boundary for the Indiana Coastal Nonpoint Pollution Control Program includes the counties adjacent to LaPorte County, Indiana, and the Calumet River basin. Figure 8 shows the Indiana portions of the watershed. About 80% of the Calumet River basin drains directly into the Indiana portion of Lake Michigan.<sup>9</sup> The remainder of the Calumet River basin drains either into Illinois or Michigan. Most of the stream flow

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<sup>8</sup> The principal pollutants identified in combined sewer overflow discharges are TSS, oxygen-depleting substances, microbial pathogens, toxics, nutrients, floatables, and trash (EPA 2007).

<sup>9</sup> In the mid-1800s, Indiana’s Lake Michigan watershed was altered so that a portion of the watershed draining to Lake Michigan was redirected to the Mississippi drainage basin.

**Table 10 Reversals of River Flow into Lake Michigan**

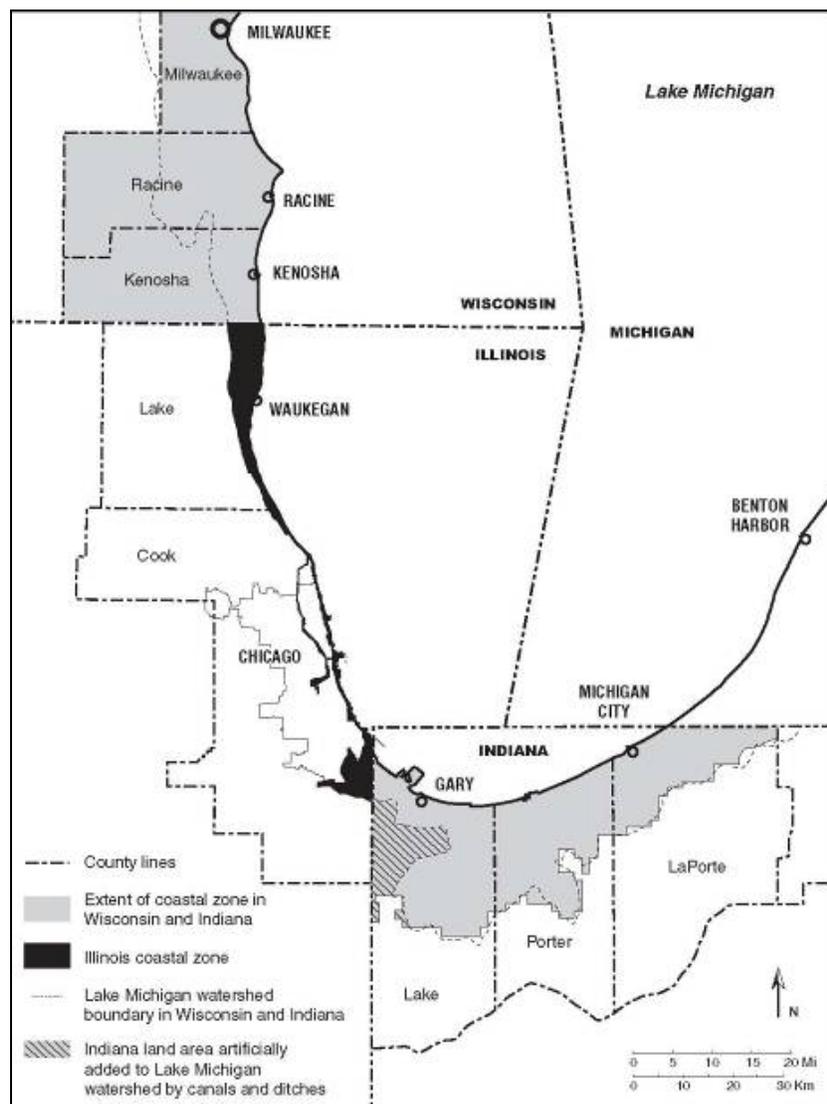
	<b>Total Volume (MG)</b>	<b>Number of Reversals</b>	<b>Volume per Reversal (MG)</b>
<b>2007</b>	224	1	224
<b>2006</b>	0.0	0	–
<b>2005</b>	0.0	0	–
<b>2004</b>	0.0	0	–
<b>2003</b>	0.0	0	–
<b>2002</b>	1,751.8	2	875.9
<b>2001</b>	1,189.0	4	297.3
<b>2000</b>	0.0	0	–
<b>1999</b>	9.7	1	9.7
<b>1998</b>	0.0	0	–
<b>1997</b>	4,738.0	5	947.6
<b>1996</b>	1,551.0	2	775.5
<b>1995</b>	0.0	0	–
<b>1994</b>	0.0	0	–
<b>1993</b>	0.0	0	–
<b>1992</b>	0.0	0	–
<b>1991</b>	0.0	0	–
<b>1990</b>	970.5	6	161.8
<b>1989</b>	52.0	1	52.0
<b>1988</b>	0.0	0	–
<b>1987</b>	1,975.0	3	658.3
<b>1986</b>	53.0	1	53.0
<b>1985</b>	211.3	2	105.7

**Source: Metropolitan Water Reclamation District of Greater Chicago (2008)**

leaving Indiana to enter Michigan eventually reaches Lake Michigan, but most, if not all, of the stream flow entering Illinois is diverted to the Mississippi River basin. The Calumet River basin drains 604 square miles in Indiana and includes portions of Lake, Porter, and LaPorte Counties; it is the primary basin affecting Indiana's portion of the Lake Michigan coast. Most of the St. Joseph River basin—the other basin draining into Lake Michigan from Indiana drainage area lies in Michigan.

*Land Use.* Roughly one-fourth of the land area in the Calumet-Galien watershed is urban (impervious, low and high density), and one-fourth is forest vegetation (shrubland, woodland, and forest). About 40% of the land area is agricultural (row crop, pasture, and small grains), and

Figure 7 Illinois Coastal Zone

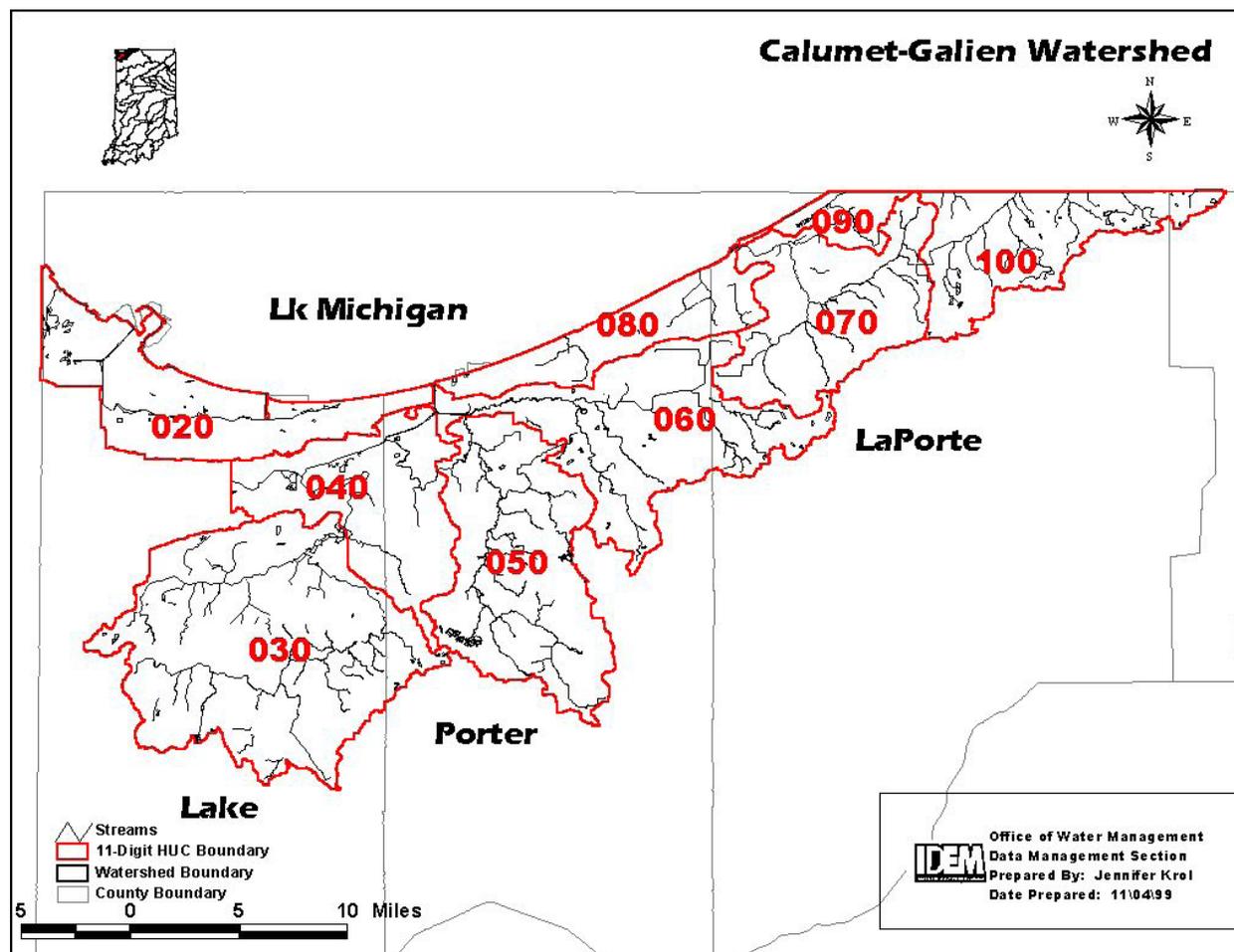


Source: Illinois DNR 2007

about 10% is wetland (Table 11 and Figure 9). Most of the soils have low- to medium-erosion potential (IDEM 2002). The watershed also includes a National Park bordered on either side by a steel mill, petroleum tank farms adjacent to residential areas, abandoned industrial sites, and transportation infrastructure.

Although not reflected in the totals shown in Table 11, the Indiana Department of Natural Resources (DNR) reports that, in 2003, there were roughly 50 livestock operations not requiring IDEM confined feeding operation permits in the watershed. Although the Indiana DNR does not report the contribution of NSP from these operations, it notes a high nutrient content of manure and runoff from confined feeding areas.

Figure 8 Calumet-Galien Watershed



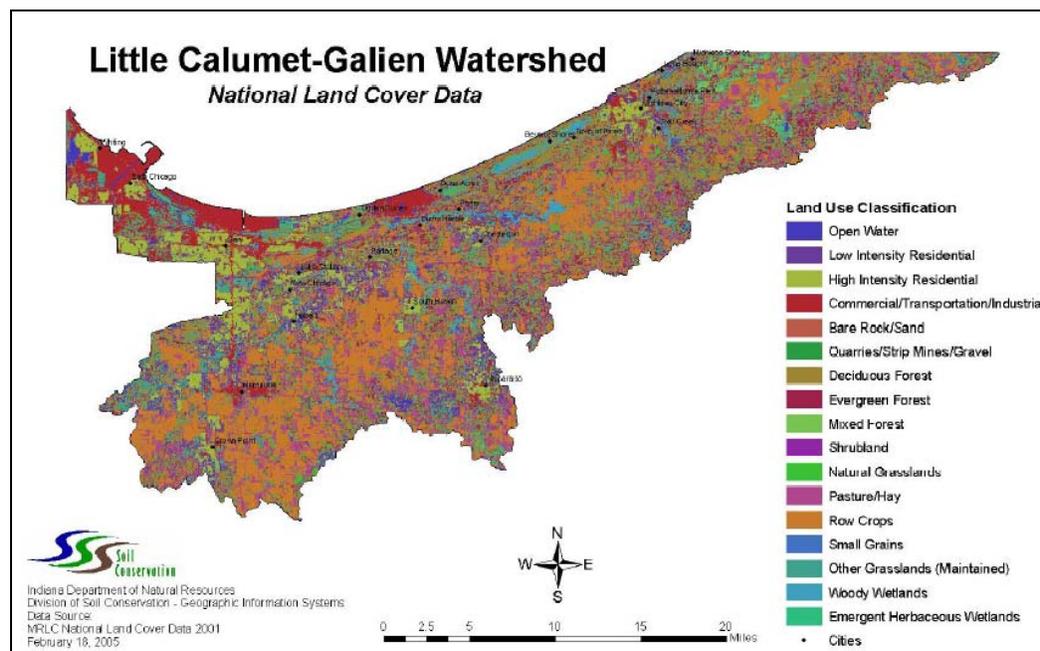
Source: Indiana DNR 2005

Table 11 Land Use in the Calumet-Galien Watershed

Description	Acres	% of Total
Open water	6,600	2%
Residential	45,346	13%
Commercial/transportation/industrial	26,938	8%
Bare rock/sand/quarries/strip mines/gravel	914	<1%
Forest	92,877	27%
Agriculture	142,803	42%
Wetlands	27,580	8%
Total	343,058	100%

Source: Indiana DNR 2005

Figure 9 Little Calumet-Galien Watershed Land Cover



Source: Indiana DNR 2005

### 5.3.3 St. Joseph River Basin–Lake Michigan Watershed

The St. Joseph River Basin–Lake Michigan Watershed, hereafter referred to as the St. Joseph River Watershed, is located in the southwestern portion of Michigan and northwestern portion of Indiana. The St. Joseph River originates in Michigan, flows through Indiana, then re-enters Michigan and flows into Lake Michigan near Benton Harbor. The watershed drains 4,685 square miles from 15 counties (Berrien, Branch, Calhoun, Cass, Hillsdale, Kalamazoo, St. Joseph, and Van Buren in Michigan and De Kalb, Elkhart, Kosciusko, LaGrange, Noble, St. Joseph, and Steuben in Indiana) (Figure 10). Roughly 60% of the drainage area is in Michigan, and the remainder is in Indiana. The watershed includes 3,742 river miles and flows through and near the metropolitan areas of Kalamazoo-Portage, Elkhart-Goshen, South Bend, and St. Joseph/Benton Harbor. According to the 2000 U.S. Census, roughly 1.5 million people reside within the watershed with slightly more than half in Michigan. The most populated county is St. Joseph, Michigan. Land use in the watershed is roughly 60% agricultural, 20% forested, and less than 10% urbanized (Figure 11). Agricultural management practices have contributed to bank erosion and sedimentation within the watershed, and NSP from agricultural fields appears to be the

**Figure 10 The St. Joseph River Watershed**

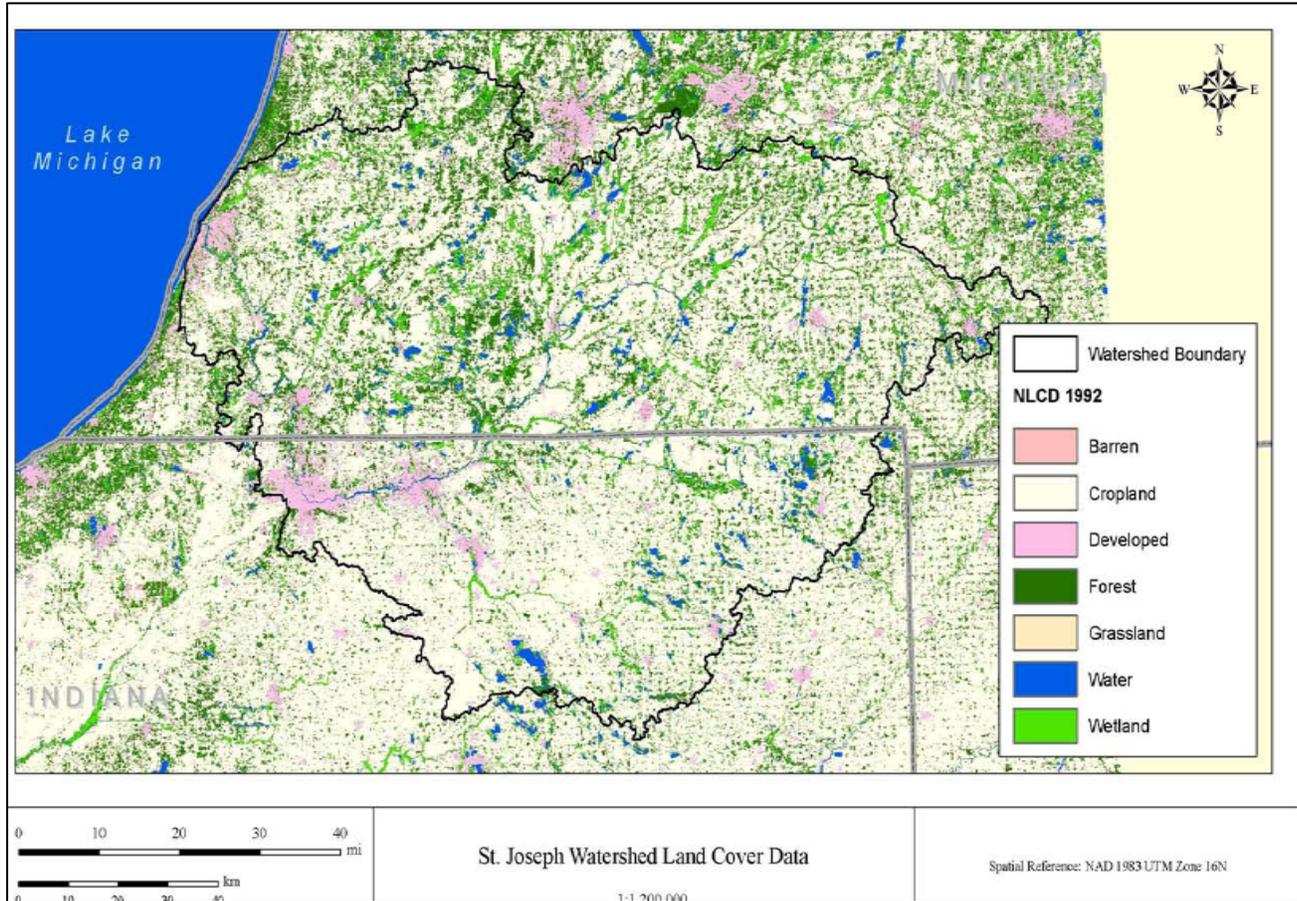
Source: USACE 2007

greatest factor contributing to degradation of water quality in the watershed (GLC 2007b). In addition, highly erodible soils, wide-ranging channel slopes, and the presence of dams all contribute to sedimentation. Known contaminants in the system include nutrients, suspended solids, mercury, atrazine, and polychlorinated biphenyls (PCBs).

#### 5.4 Nonpoint Pollutant Sources and Loadings

This section describes the sources and characteristics of three key pollutants considered in this phase of the effort (TSS, ammonia, and mercury). In addition, nitrogen is an important nonpoint source pollutant that can contribute to the ammonia levels in water. Therefore, nonpoint sourced information on nitrogen is presented also. Developing detailed estimates of NSP loadings of these pollutants to southern Lake Michigan would require data and modeling efforts that are beyond the scope of this study. However, the application of the results of NSP studies of these pollutants in other areas provides some very rough estimates of their loadings to southern Lake Michigan.

Figure 11 National Land Cover Data Set for the St. Joseph River Watershed, 1992



Source: USACE 2007

#### 5.4.1 TSS

TSS are organic and inorganic solid materials suspended in water. They include silt, plankton, industrial wastes, soil, algae, and fine particles of plant material. Suspended solids can result from erosion from urban runoff and agricultural land, construction sites, mining operations, logging operations, industrial wastes, bank erosion, stream erosion, algae growth, and wastewater discharges. Table 12 shows a variety of TSS sources and highlights how TSS are generated.

Sediments from different sources vary in the kinds and amounts of pollutants that are adsorbed to the particles. For example, sheet, rill, ephemeral gully, and wind erosion mainly move soil particles from the surface or plow layer of the soil. Sediment that originates from surface soil has a higher pollution potential than that from subsurface soils. The topsoil of a field is usually richer in nutrients and other chemicals because of past fertilizer and pesticide applications, as well as nutrient cycling and biological activity. Topsoil is also more likely to have a greater percentage of organic matter. Sediment from gullies and streambanks usually carries less adsorbed pollutants than sediment from surface soils.

Table 12 Sources of TSS

Source	Generation Modes
<b>Agriculture</b>	Cropping too close to ditches, drains, and watercourses can accelerate bank erosion. Access to watercourses by livestock can lead to the loss of riparian vegetation and deterioration of shoreline leading to sediment pollution.
<b>Dams and reservoirs</b>	Act as settling basins for silt and other suspended materials.
<b>Dredging</b>	Destabilizes substrate and the associated benthic community. Alters water circulation patterns and submarine mudflows. Can redistribute sediments at disposal sites, sometimes smothering benthic organisms. Produces localized changes in water chemistry, including reduced dissolved oxygen levels, and increased turbidity.
<b>Erosion</b>	Primary source of suspended solids in coastal zones. Accelerated by human activities that remove vegetative cover and expose soil.
<b>Flooding</b>	High concentrations of suspended solids may persist in rivers.
<b>Forest fires</b>	Runoff from burned catchments increases due to accelerated overland flow rates (from reduced infiltration capacity).
<b>Logging activities</b>	Accelerates surface erosion and sedimentation, which continue after logging activity ceases.
<b>Mining</b>	Runoff from mine spoils, coal washing, granite crushing, etc., can increase suspended sediment concentrations.
<b>Recreational boating and navigation</b>	Resuspends sediments, thereby increasing turbidity. Wave wash erodes material from riverbanks and lake shorelines.
<b>Roads</b>	Road construction and associated culvert installation result in dramatic short-term increases in suspended sediment. Disruption and/or removal of riparian vegetation. Destabilized shoreline and sediment from backfill associated with bridge construction and stream crossings.
<b>Urban development</b>	Increased soil exposure and sediment loads from topsoil removal. Releases sediments and other compounds from storm sewers and street runoff.
<b>Wind/wave/current action</b>	Resuspension and transport of substrate sediments.
<b>Ice breakup and movement</b>	Ice scouring increases shoreline erosion. Releases sediments from melting ice and snow. Increases sediment transport.

Source: Kerr 1995

In 2003, the USGS and the EPA began a cooperative study to describe the distribution of concentrations and annual yields (load per unit area of the basin) throughout the Great Lakes region and adjacent areas (Robertson et al. 2006). Annual loads were calculated by summing daily loads. Daily loads were calculated on the basis of relationships between constituent loads, stream flow, and time of year for each of 550 sites from 1971 to 2002. Total annual loads were then calculated for all years that had no missing daily values, and median annual loads and concentrations were then computed for each site. For all sites, the median TSS yield was 35,400 kg/km<sup>2</sup>/yr and the mean was 85,100 kg/km<sup>2</sup>/yr. The minimum was 22 kg/km<sup>2</sup>/yr and the maximum was 3,373,000 kg/km<sup>2</sup>/yr.

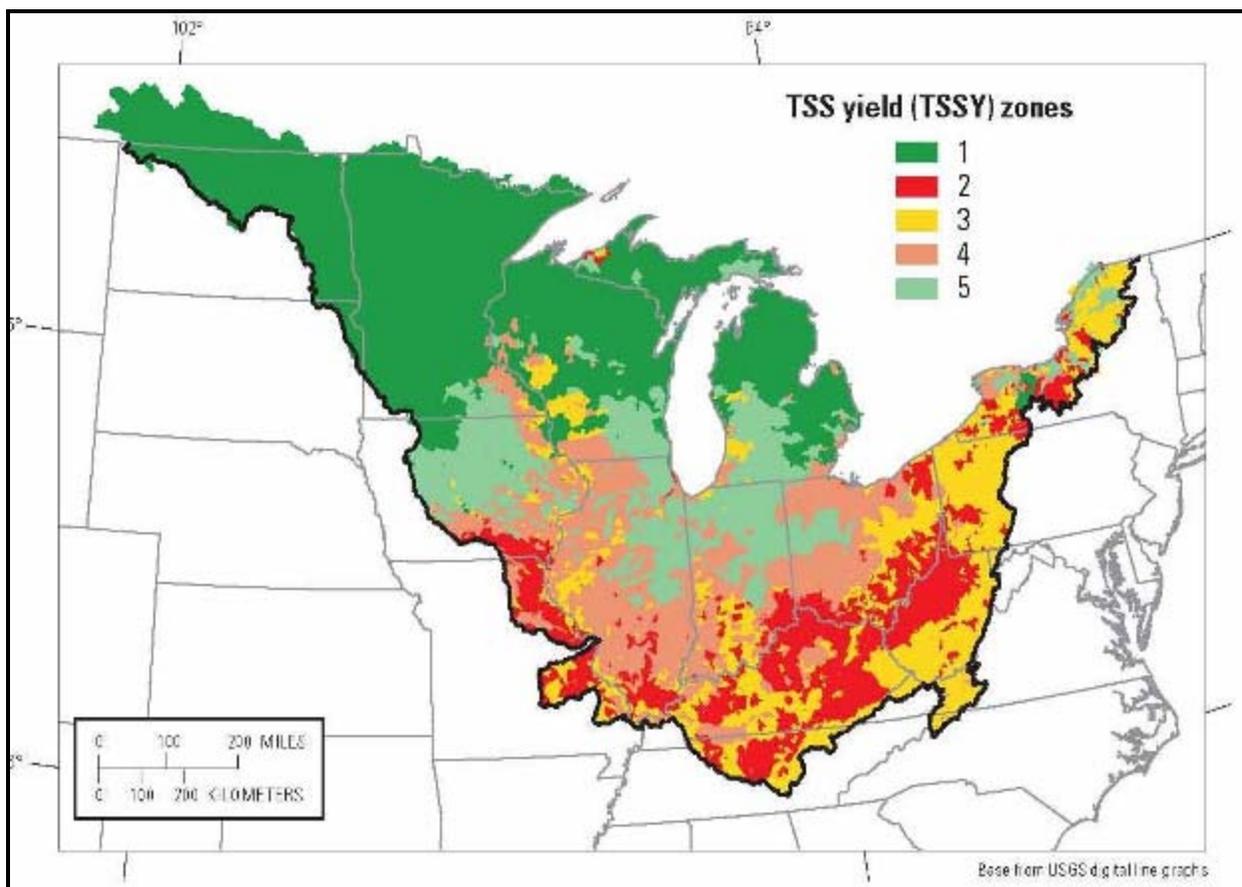
Regression analyses that related yields to various environmental factors showed that annual yields were most highly correlated with soil properties in the basin, air temperature, precipitation, evaporation, and the resulting runoff. The percentages of wetlands and agricultural lands in the basin also correlated with TSS yields. The authors developed five different zone categories to delineate areas with similar environmental characteristics and reference (or background) median concentrations and yields. These TSS yield zones described the differences in reference concentrations better than the national nutrient ecoregions that were delineated primarily by the distributions of different types of land use. The average TSS yield data varied with zone, ranging from 785 kg/km<sup>2</sup>/yr in Zone 5 to 108,000 kg/km<sup>2</sup>/yr in Zone 4. The zones bordering the southern part of Lake Michigan are (in roughly equal amounts) Zones 3, 4, and 5, with median TSS yields of 27,600, 108,000, and 785 kg/km<sup>2</sup>/yr, respectively (Figure 12).

The USGS study does not provide the level of detail needed to estimate total annual loadings from the southern Lake Michigan watersheds using the zone-specific loading rates. However, a rough estimate of the amount of TSS entering southern Lake Michigan can be made by using average TSS loading factors developed by Kieser & Associates (2003) for a St. Joseph River Watershed sediment model. Kieser & Associates used earlier data reported by Robertson indicating that the St. Joseph River Basin watershed contributed 102,000 kg/km<sup>2</sup> of TSS to Lake Michigan each year. By subtracting from this total the roughly 1.4% of TSS load that is contributed by point sources, the NSP loading is roughly 101,600 kg/km<sup>2</sup>, or about 360,000 kg/mi<sup>2</sup>. This estimate is consistent with the USGS loadings described above. The application of this average NSP loading rate to the 4,685 mi<sup>2</sup> St. Joseph River Watershed and the 604 mi<sup>2</sup> Calumet-Galien Watershed suggests that roughly  $1.4 \times 10^9$  kg, or about 1.5 million tons, of NSP TSS enter southern Lake Michigan per year from these two watersheds. As noted earlier, most of the water in the Chicago Watershed drains away from Lake Michigan, and this 1.5 million-ton estimate does not include any NSP TSS coming from the Chicago watershed.

#### **5.4.2 Ammonia**

Ammonia emissions come from a variety of rural and urban sources, many of which are diffuse or unregulated. Examples of nonpoint ammonia sources include fertilizers, livestock, untreated septic effluent, and decaying organisms. These and other sources of urban and rural ammonia emissions are identified in Table 13.

**Figure 12 USGS TSS Yield Zones (Zone 1 has the lowest yield, and Zone 5 has the highest yield)**



**Source: Robertson et al. 2006**

Despite the variety of ammonia sources, EPA emission inventory data indicate that livestock management and fertilizer application contributed about 85% of total ammonia emissions in the United States in 1998, and that publicly owned treatment works (POTWs), mobile sources, and combustion sources combined contributed about 15% of the total (EPA 2000b).

Studies of coastal waters, particularly the Chesapeake Bay, indicate that small particles of ammonia can be transported short and long distances through the air before falling onto the surrounding land and water. Volatilized ammonia can travel hundreds of miles from its origin. European scientists have found that nitrogen pollution in the Mediterranean Sea is caused in large part by ammonia emissions in northern Europe (Gay 2005). Because an area's air shed can be considerably larger than its watershed, sources both within and beyond the watershed need to be considered when estimating airborne ammonia emissions.

There has been relatively little research on ammonia emissions in the United States. Although research is increasing and measurement equipment and methods are being developed, the high

**Table 13 Sources of Ammonia Emissions**

Rural Sources	Urban sources
<ul style="list-style-type: none"> <li>• Decomposition of livestock and poultry wastes</li> <li>• Natural biological cycling (due to biotic processes in soils and waters)</li> <li>• Fertilizer application</li> <li>• Landfills</li> <li>• Composting</li> <li>• Geothermal emissions</li> <li>• Combustion—biomass (forest fires and agricultural fires)</li> </ul>	<ul style="list-style-type: none"> <li>• Mobile sources</li> <li>• Wastewater treatment plants (including sewage sludge)</li> <li>• Fossil fuel combustion—industrial, commercial, and residential</li> <li>• Nitrogenous materials manufacturing (fertilizers, etc.)</li> <li>• Fossil fuels processing (coke production, catalytic cracking)</li> <li>• Ammonia injection as a control measure (power generation plants)</li> <li>• Ammonia refrigeration</li> <li>• Domestic sources (solvent use, cleaners, untreated wastes, etc.)</li> <li>• Commercial ammonia use (printing processes—blueprints, solvents, cleaners, etc.)</li> </ul>

**Source: EPA 1995**

costs associated with measurement and the lack of continuous measurement capability has hindered the development of reliable annual emission factors. Typically, data are collected over short durations, and extrapolations beyond the sampling periods and conditions are prone to error (Arogo et al. 2001). Nonetheless, some site-specific studies have been conducted. Two are used here to provide a rough estimate of potential ammonia emissions to southern Lake Michigan from air deposition. The first study (Anderson et al., undated) reports an estimated global average emission factor of 3.6 kg/mi<sup>2</sup> per year for ammonia emissions from undisturbed soil and vegetation. The second (Scudlark et al. 2001) calculated a direct atmospheric deposition rate of gaseous ammonia to the Delaware Inland Bays of 3.0 to 4.8 kg/ha/yr. By taking the midpoint of this range and converting it to kg/mi<sup>2</sup>, we calculate a deposition rate range of 9.3 kg/mi<sup>2</sup> (undisturbed soil) to 1,010 kg/mi<sup>2</sup> (for an area with intense poultry production). Lacking deposition factors specific to the southern Lake Michigan region, not knowing the amount of land used for poultry farming in the watersheds that drain into southern Lake Michigan, and lacking estimated deposition rates for sources other than poultry farming, we assume a weighted average rate of 13.6 kg/mi<sup>2</sup> (assuming 1% of the area is at the high end of the estimate range and 99% at the lower end). By multiplying this weighted average estimate by the estimated surface area of southern Lake Michigan (2,800 mi<sup>2</sup>)<sup>10</sup> we obtain a very rough annual estimate of about 103,000 kg (about 113 tons) of ammonia deposited directly into the lake each year. This estimate does not account for indirect deposition.

<sup>10</sup> The surface area of Lake Michigan is 22,400 square miles. Assuming that the southern portion of the lake is roughly one-eighth of the total surface areas, the surface area of southern lake Michigan is estimated to be roughly 2,800 square miles, or 725,200 hectares.

### 5.4.3 Nitrogen

Nitrogen is a nutrient needed for plant growth, and although it is naturally present in soils, additional nitrogen is added to increase crop production. Such additions come from the application of commercial fertilizers and manure, the incorporation of crop residues, and the growing of legumes in the soil (biological nitrogen fixation). Not all nitrogen that is present in or on the soil is available for plant use at any one time. For example, in the eastern Corn Belt, it is normally assumed that about 50% of applied nitrogen is assimilated by crops during the year of application. Organic nitrogen normally constitutes the majority of the soil nitrogen. It is slowly converted (2 to 3% per year) to the more readily plant-available inorganic ammonium or nitrate (EPA 2003).

The chemical form of nitrogen affects its impact on water quality. The most biologically important inorganic forms of nitrogen are ammonium ( $\text{NH}_4^+$ ), nitrate ( $\text{NO}_3^+$ ), and nitrite ( $\text{NO}_2^+$ ). Organic nitrogen occurs as particulate matter, in living organisms, and as detritus. It occurs in dissolved form in compounds such as amino acids, amines, urines, and urea. Nitrates are water-soluble, highly mobile, and can move freely with drainage water into both surface and groundwater supplies. They can also be transported with surface runoff, but not usually in large quantities. Ammonium, on the other hand, becomes adsorbed to the soil and is lost primarily with eroding sediment. Even if nitrogen is not in a readily available form as it leaves the field, it can be converted to an available form either during transport or after delivery to water bodies. Nitrate sources include cropland, nurseries, orchards, livestock operations, gardens, lawns, forests, and landfills.

Agricultural sources are generally considered to be the predominant contributors to nonpoint nitrogen pollution, and although we have been unable to find data on the shares of contributions by different sources to Lake Michigan, a recent study (Alexander et al. 2008) has estimated sources of nitrogen delivery to the Gulf of Mexico from the Mississippi Basin. These shares were as follows: corn and soybean cultivation (52%), atmospheric deposition (16%), urban and population-related sources (9%), pasture/rangeland (5%), forest (4%), wheat (4%), alfalfa (3%), other crops (7%), and shrub lands and barren lands (0.1% each).

EPA (2000a) identifies the following key sources of nitrogen reaching surface waters via routes other than the atmosphere:

- fertilizer from agricultural operations, recreation areas, suburban lawns;
- manure from animal production facilities;
- municipal and industrial treatment plant sludge and effluent and residential septic tanks;
- crop residues (especially nitrogen-fixing crops such as legumes); and
- industrial wastes.

#### 5.4.3.1 Air Deposition of Nitrogen (ADN)

The discussion in this section comes from EPA's report, *Deposition of Air Pollutants to the Great Waters Third Report to Congress* (EPA 2000a). Nitrogen comprises 78 percent of the atmosphere by weight, primarily in the form of inert  $\text{N}_2$ . A small fraction of atmospheric

nitrogen exists in more chemically and biologically active forms, such as nitrogen oxide gases, nitric acid vapor, particulate and dissolved nitrate, gaseous ammonia, dissolved ammonium, ammonium particulates, and organic nitrogen compounds. These forms are active in the nitrogen cycle, which involves the atmosphere, photochemistry, plants, animals, microbes, soils, surface waters, and the oceans. Although reactive nitrogen compounds are produced naturally by several processes, a significant portion of the reactive nitrogen is released to the atmosphere through fossil-fuel combustion, fertilizer application, and intensive animal agriculture. Precipitation readily removes most reactive nitrogen compounds, such as ammonia and nitrogen oxides, from the atmosphere. These compounds are subsequently available as nutrients to aquatic and terrestrial ecosystems.

The total load of atmospherically deposited nitrogen to a water body, in this case, Lake Michigan, is the sum of the nitrogen deposited directly to the surface of the water, plus a portion of the nitrogen deposited to the watersheds. Although only a fraction of the atmospheric nitrogen deposited to watersheds ultimately reaches downstream water bodies, ADN transfer from watersheds is nevertheless the more important pathway for introduction of ADN. This is due to the much larger areal extent of watersheds relative to the surface areas of the receiving water bodies.

The portion of ADN transferred from watersheds to downstream water bodies is still relatively uncertain, and although several ongoing projects are attempting to quantify this, the rate of such transfer remains one of the greatest sources of uncertainty in estimating nitrogen and ADN loadings to surface waters. Transfer rates appear to vary greatly among watersheds and among areas within watersheds. For example, estimates of ADN transfer rates from various watershed areas to Great Bay Estuary, New Hampshire, range from 3 to 6 % for wetlands, forests, and disturbed open land to 90% for surface water in the watershed. Estimated overall ADN transfer rates for the watersheds of several coastal water bodies (as developed by a number of researchers using a variety of techniques) range from 7 to 19% and average 12%.<sup>11</sup>

Over the past five years, an average of 5.3 kg/ha of inorganic nitrogen as nitrate and ammonium nitrogen were deposited in precipitation at the monitoring station located at the southern tip of Lake Michigan—the closest to the study area (NADP 2008).<sup>12</sup> By assuming that the southern portion of the lake is roughly 2,800 square miles, or 725,200 ha, and that the average annual deposition rate is 5.3 kg/hectare, it can be estimated that roughly 3.8 million kg of nitrogen are deposited directly into the southern portion of the lake each year. In addition, an estimated 880,000 kg of nitrogen deposited onto the watersheds surrounding the southern portion of the lake could be expected to enter southern Lake Michigan via runoff.<sup>13</sup> By summing the estimated

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<sup>11</sup> The studied watersheds and their respective estimated atmospheric nitrogen deposition rates are as follows: Albemarle Pamlico Sounds (15%), Chesapeake Bay (15%), Delaware (9.4%), Long Island Sound (15%), Narragansett Bay (7%), New York Bight (12%), and Waquoit Bay (11%).

<sup>12</sup> The reported rates of nitrogen deposition in kg/ha for the latest 5 years for which data are available are as follows: 8.1 in 2006, 5.0 in 2005, 5.7 in 2004, 7.6 in 2003, and 5.3 in 2002 (NADP 2008)

<sup>13</sup> The estimated land area of the watersheds bordering southern Lake Michigan is 5,289 square miles (604 square miles in the Calumet-Galien and 4,685 square miles in the St. Joseph watershed). We assume that on average, 12% of the estimated 7.3 million kg of nitrogen deposited onto the watersheds reaches the lake.

direct and indirect depositions, we estimate a total of about 4.7 million kg, or about 5,100 tons of deposited per year.

As with all dry deposition processes, nitrogen dry deposition is extremely difficult and expensive to monitor directly, and no programs currently do this (EPA 2000a). The lack of a reliable approach for quantifying dry deposition remains a significant gap in the understanding of nitrogen deposition processes and effects. Dry deposition can be inferred based on the nitrogen content of atmospheric gases and particles and computed deposition rates. According to EPA (2000a), two networks are using this approach: the National Oceanic and Atmospheric Administration's (NOAA's) Atmospheric Integrated Research Monitoring Network (AIRMoN-dry) and the EPA-sponsored Clean Air Status and Trends Network (CASTNet). However, extrapolation of inferred nitrogen dry deposition values to surrounding areas is unreliable and is still under investigation. In the absence of measured nitrogen dry deposition rates, many investigators have attempted to estimate dry deposition based on a ratio of dry deposition to wet deposition. A 1:1 ratio is most commonly derived; however, this approach also introduces considerable uncertainty, and the 1:1 ratio is applicable only for oxidized inorganic nitrogen, not ammonium compounds (EPA 2000a).

#### 5.4.4 Mercury

Nonpoint sources of mercury emissions include mining operations, vehicle emissions, urban runoff, roads, parking lots, and landfills. River transport is an important vector for mobilization of mercury in the Great Lakes Basin.

- Research indicates that a number of factors influence whether mercury that is deposited to watersheds or tributaries will be transported to the lake itself. The principal factors that affect mercury loading to the aquatic ecosystem appear to be the amount of annual precipitation;
- the influence of the urban air plume (in terms of local deposition of the contaminated plume);
- storms and other events, such as snowmelt, which influence stream flow and the resuspension of particle-bound mercury in sediments; and
- prevailing land use (e.g., forestry, agriculture, urban).

Some of these factors appear to influence the amount of mercury in throughfall (i.e., precipitation that has washed through the forest canopy) and litterfall (i.e., fallen leaves) as well as the amount of mercury that is sequestered in organic soils, preventing its transport through the watershed (EPA 2000a).

The following information comes from EPA (2000a). Pirrone et al. (1998) estimated atmospheric emissions and deposition of mercury in North America and compared these estimates to vertical profiles of mercury accumulation rates in sediment cores from four Great Lakes sites. The results of this analysis illustrate that atmospheric deposition has been significant since the 1900s and remaining the major contributor of mercury to the Great Lakes, although a variety of other sources (including direct discharges) also contribute to mercury inputs in the Great Lakes. Based on sediment core data and emissions estimates, Pirrone et al. calculated the atmospheric deposition flux of mercury to North America to be between 14.3 and 19.8  $\mu\text{g}/\text{m}^2/\text{yr}$  (1.43 to 1.98  $\text{ng}/\text{cm}^2/\text{yr}$ ), whereas in the Great Lakes region, the atmospheric deposition flux of mercury

was calculated to be higher, at  $135 \mu\text{g}/\text{m}^2/\text{yr}$  ( $13.5 \text{ ng}/\text{cm}^2/\text{yr}$ ). This difference is likely due to local anthropogenic emissions and subsequent deposition of mercury in the Great Lakes region. Furthermore, mercury accumulation rates in sediment cores from the Great Lakes from preindustrial to modern times increased from 0.7 to  $235 \text{ ng}/\text{cm}^2/\text{yr}$  in Lake Ontario, from 0.8 to  $65 \text{ ng}/\text{cm}^2/\text{yr}$  in Lake Michigan, and from 3 to  $175 \text{ ng}/\text{cm}^2/\text{yr}$  in Lake Erie. All of these values are larger than those reported in sediment cores from small remote lakes in the northeastern United States, indicating that local and regional sources of mercury are deposited in the Great Lakes region rather than simply from the regional background in the northeastern United States.

One of the other studies reported by EPA (2000a) involved a hybrid-modeling framework based on monitoring data in the Great Lakes region conducted by Landis (1998). Annual deposition estimates from the Landis study are provided in Table 14. The Landis modeling effort indicated that the Chicago/Gary urban area was responsible for at least 19% of the total atmospheric deposition to Lake Michigan. It should be noted that reactive mercury deposition is not included in this estimate of the urban influence and, thus, the percentage likely represents an underestimate of the true impact of the Chicago/Gary urban area (EPA 2000a).

**Table 14 Preliminary Estimates of Total Atmospheric Mercury Deposition to Lake Michigan**

<b>Deposition</b>	<b>Annual Total (kg)</b>	<b>Annual Mean (<math>\mu\text{g}/\text{m}^2</math>)</b>
Wet	$614 \pm 186$	$10.6 \pm 3.2$
Aerosol dry	$69 \pm 38$	$1.2 \pm 0.7$
Reactive gaseous mercury	506	8.8
Dissolved gaseous mercury	-460	-8.0
Total	729	12.6

**Source: EPA 2000a**

Assuming that southern Lake Michigan is roughly one-eighth of the total surface area of the lake, and the total annual mercury deposition to the lake is 729 kg, one could infer that roughly 91 kg per year of mercury are deposited by air deposition in southern Lake Michigan. Further, if air deposition contributes about 80 to 84% of total mercury entering the lake (GAO 2005), the total amount entering southern Lake Michigan would be about 111 kg/yr. However, this may underestimate total southern Lake Michigan mercury loadings, as the Landis study reports that the Chicago/Gary area alone was responsible for at least 19% of the total atmospheric deposition to Lake Michigan.

In the 1990s, federal, state, and academic scientists evaluated Lake Michigan-wide contaminant transport for four pollutants, one of which was mercury.<sup>14</sup> The Lake Michigan Mass Balance Project (LMMBP) was a coordinated effort to monitor tributary and atmospheric pollutant loads, develop source inventories of toxic substances, and evaluate the fates and effects of these pollutants in Lake Michigan. As part of that project, the mercury loadings via tributaries to the lake were evaluated. As reported in Hurley et al. (2000), full-scale tributary sampling was

<sup>14</sup> The others were PCBs, trans-Nonachlor, and atrazine.

conducted during two hydrologic years, from March 1994 through October 1995. Hurley et al. discuss the riverine concentrations and fluxes of total mercury and methylmercury (shown in Table 15 as Hg<sub>T</sub> and MeHg, respectively). Because inorganic mercury has been shown to be converted to the bioaccumulative methylmercury form in watersheds, the importance of specific tributaries in delivering the bioaccumulative form of mercury to nearshore regions of Lake Michigan was also assessed. During 1995, all 11 study tributaries were also sampled for methylmercury. Three tributaries in southern Lake Michigan were included in the study. Table 15 summarizes the results for those tributaries.

**Table 15 Watershed Characteristics and Mercury Concentrations for Southern Lake Michigan Tributaries, 1995**

Tributary	Drainage Area (km <sup>2</sup> )	Land Use/Land Cover (%)				Samples (n)	Mean Concentration		% as MeHg
		Urban	Agri-culture	Forest	Wetlands		Hg <sub>T</sub> (ng/L)	MeHg (ng/L)	
Grand	14,395	5.5	75.5	13.9	3.7	21	3.82	0.111	2.91
Indiana Harbor Ship Canal	179	78.2	1.5	3.0	6.2	9	10.23	0.050	0.48
St. Joseph	12,155	5.5	80.5	9.3	2.4	16	5.32	0.106	1.99

Source: Hurley et al. 2000

The highest concentrations of total mercury occurred in the industrialized Indiana Harbor Ship Canal. In contrast to total mercury, concentrations of methylmercury were not highest in the anthropogenically influenced sites. The lowest methylmercury concentrations (in all 11 tributaries studied) were in the Indiana Harbor Ship Canal. Hurley et al. suggest that although total mercury concentrations were elevated, the form of mercury in these contaminated sites was not available for transformation to the bioaccumulative methylmercury form. They also note that the results suggest differing reactivities of total mercury in contrasting watersheds. They report that wetlands are significant sites of mercury methylation and that forested regions can also contribute to methylmercury inputs. They say that in addition to using simple watershed coverages to explain mercury dynamics, it is most likely important to consider hydrologic flow paths and connectivity of specific land cover types to the main river channel. The authors note that despite elevated total mercury levels in the Indiana Harbor Ship Canal, where particles contain over 1 µg/g mercury on a dry weight basis, relatively little methylmercury is produced. Taken together, the above results suggest substantially different reactivities of inorganic mercury among tributaries (Hurley et al. 2000).

Facing similar challenges regarding mercury contamination in the environment (a high proportion of tested lakes receive restrictive fish consumption advisories) and recognizing that virtually all of the mercury contaminating the Great Lakes is delivered by the atmosphere, the state environmental offices in Michigan, Wisconsin, and Minnesota applied for and received a grant from EPA to develop and use quantitative tools to identify sources of mercury to the atmosphere. The findings regarding mercury emissions and sources in Michigan are summarized in Table 16. On a percentage basis, the results for Minnesota and Wisconsin are similar, although

Table 16 Estimated Anthropogenic Mercury Air Emissions in Michigan, 1999

Emission Source Categories	Hg Emissions (lb/yr)	% of State Total
<b>FUEL COMBUSTION</b>		
<b>Coal Combustion</b>		
Electric utilities	2,591	56.7%
Residential	6	< 1%
Industrial/commercial	134	2.9%
<b>Natural Gas Combustion</b>		
Electric utilities	6	< 1%
Industrial/commercial	238	5.2%
Residential	91	2%
<b>Oil Combustion</b>		
Electric utilities	61	1.3%
Industrial/commercial	92	2%
Residential	88	1.9%
<b>Wood combustion</b>		
Electric utilities	4	<1%
Industrial/commercial	5	< 1%
<b>FUEL COMBUSTION TOTAL</b>	<b>3,316</b>	<b>72.5%</b>
<b>INCINERATION</b>		
Hospital waste	6–10	< 1%
Municipal waste	176	3.8%
Sewage	162	3.5%
<b>INCINERATION TOTAL</b>	<b>348</b>	<b>7.6%</b>
<b>INDUSTRIAL SOURCES</b>		
Brick manufacturing	1	1%
Cement manufacturing	67	1.5%
Steel manufacturing (electric arc furnaces)	104	2.3%
Natural gas production	2	< 1%
Secondary metal production	332	6.6%
Thermometer manufacturing	3	< 1%
<b>INDUSTRIAL SOURCE TOTAL</b>	<b>509</b>	<b>11.1%</b>
<b>AREA SOURCES</b>		
Cremation	10	< 1%
Lamp manufacturing/breakage	69	1.5%
<b>AREA SOURCE TOTAL</b>	<b>132</b>	<b>2.8%</b>
<b>MOBILE SOURCES</b>		
On road	262	5.7%
Nonroad	6	< 1%
<b>MOBILE SOURCE TOTAL</b>	<b>268</b>	<b>5.7%</b>
<b>TOTAL Mercury Air Emissions</b>	<b>4,573</b>	<b>100%</b>

Source: Morgan et al. 2003

the total estimated anthropogenic mercury emissions were 3,577 lb for Minnesota and 6,604 lb for Wisconsin, compared with 4,573 lb for Michigan (Morgan et al. 2003).

Insufficient data were available to develop NSP loadings for chromium, vanadium, and selenium. The point source data for total nitrogen were so sparse that calculation of a point source load for total nitrogen was not possible. From the nonpoint side, however, we were able to estimate a total nitrogen load of 5,100 tons/yr, which corresponds to 28,000 lb/day.

## 5.5 NSP Summary

NSP contributes significant quantities of TSS, nutrients, ammonia, and mercury into waterways. Sources include runoff (both agricultural and urban), atmospheric deposition, hydromodification, marina and recreational boating, and sediments.

The two main watersheds that drain into Lake Michigan are the Calumet-Galien and the St. Joseph River watersheds. (Because many of the Illinois rivers within the Phase I study area have been engineered to drain away from Lake Michigan, the Chicago Watershed, even though it borders the Lake, does not drain into it.) Combined, the Calumet-Galien and St. Joseph River watersheds drain roughly 5,300 square miles of land and water into the southern portion of the lake. Land use in the combined watersheds is roughly 60% agriculture, 20% forest, 10% urban, and 10% other.

The scope of this study did not allow for the design and use of models needed to develop detailed estimates of the NSP loads entering southern Lake Michigan. However, we have made some very rough estimates of the annual loads of the key pollutants by extrapolating the results of other NSP studies to the southern Lake Michigan region. The estimated annual loadings using this approach are TSS, 1.5 million tons; total nitrogen, 5,100 tons; ammonia, 113 tons; and mercury, 0.12 ton. To allow comparison to the point source loadings, the loadings were converted to units of lb/day: TSS, 8.2 million lb/day; total nitrogen, 28,000 lb/day; ammonia, 619 lb/day; and mercury, 0.67 lb/day.

## Chapter 6 Discussion

The target pollutants can enter Lake Michigan from many sources. Chapter 4 presents the detailed discharge data from a selected group of 80 industrial and municipal facilities for all of the target pollutants. Chapter 5 provides a review of nonpoint sources and makes estimates for TSS, ammonia, and mercury loadings. This chapter offers an overview of the Phase I study area and tries to place the loadings into context. This chapter also offers discussion on the uncertainty of the assumptions, data, and analyses used to generate estimates.

### 6.1 Comparison of Quantified Sources

Table 17 provides a comparison of the point source loads (represented by the average DMR data, except for vanadium) and the nonpoint source loads, as estimated at the end of Chapter 5. Comparison of loads is possible for three of the target pollutants.

**Table 17 Comparison of Point and Nonpoint Source Loads to the Phase I Study Area**

<b>Pollutant</b>	<b>Average Point Source Estimate (lb/day)</b>	<b>Average Nonpoint Source Estimate (lb/day)</b>
TSS	57,376	8,200,000
Ammonia	2,245	619
Total chromium	11.8	No data
Hexavalent chromium	1.8	No data
Mercury	0.024	0.67
Vanadium	26.6 <sup>a</sup>	No data
Selenium	2.8	No data
Total nitrogen	No data	28,000

<sup>a</sup> The vanadium value is taken from the TRI data set rather than from the DMR data set.

#### 6.1.1 TSS

The TSS load is dominated by the nonpoint source contributions. TSS discharges from nonpoint sources tend to be intermittent, with large releases occurring during heavy precipitation and minimal releases occurring other times. With some exceptions, point source discharges for TSS are relatively consistent.

EPA (2005) suggests that the average TSS concentration in urban runoff (presumably averaged over the duration of the rain event) is 80 mg/L. In the event of a 0.5-inch rainfall over a 1 mi<sup>2</sup> area with the assumption that half of the stormwater runs off (and that the other half infiltrates, evaporates, or is captured and treated), the total runoff volume would be 8.7 million gallons or 32.8 million liters. If TSS averages 80 mg/L, the total runoff load would be 2,627 kg/mi<sup>2</sup> or about 5,780 lb/mi<sup>2</sup>. If an urban/suburban area covers 10 mi<sup>2</sup>, the resulting runoff from a 0.5-inch rainfall would be about the same as the average daily point source discharge from the entire Phase I study area.

As a point of context, it is useful to demonstrate how much material is represented by the daily point source load of 57,376 lb/day. Water weighs 8.33 lb/gal. The specific gravity for soils is about 2.6. Therefore, a gallon of soil weighs about 21.7 lb. The daily point source load represents a solids load equivalent to 2,644 gallons of soil. A typical household trash can holds 30 gallons; this quantity of soil would fill about 88 trash cans each day. In this context, the TSS load spread across the entire Phase I study area should not have much effect on overall water quality. Locally, however, large loadings of solids can smother stream/river/lake beds and harm the aquatic plants and animals that live there.

### **6.1.2 Mercury**

Comparison of the point and nonpoint loads of mercury show that nonpoint source contributions are 28 times higher. Although nonpoint sources are almost certainly much larger than point sources, the actual ratio of the sources may be misleading because many point sources have not yet begun sampling of the discharges for mercury. Issues relating to monitoring, reporting, and entering point source concentrations for mercury in units of ng/L were discussed in Section 3.3.2.

### **6.1.3 Ammonia and Total Nitrogen**

Direct comparison of ammonia loads shows that point source loads are about 3.6 times higher than nonpoint source loads. However, if the large total nitrogen load from nonpoint sources is also considered, it is likely that the overall nitrogen nonpoint source contribution is larger. Although the total nitrogen is not likely to have a near-field toxic effect to the extent that ammonia-nitrogen does, it will have a comparable nutrient effect on water quality.

## **6.2 Other Unquantified Sources**

Using the available data and literature, this study has generated loading estimates for some of the target pollutants. Some of the pollutants (e.g., selenium and vanadium) are not monitored frequently in either point or nonpoint discharges. Even though point source loading estimates were generated for those pollutants, they were based on only a few data points. The actual total point source loading is probably higher, but without data, it cannot be accurately estimated.

Several other examples of contributing sources that have not been quantified are described below.

### **6.2.1 TSS**

A source of TSS not included in these estimates is resuspension of sediments. Wind and wave action or scouring from vessel propeller wash can cause sediments to become resuspended in the water column. These are not new releases of sediment, but they may affect aquatic organisms in a manner similar to new releases.

### 6.2.2 Ammonia and Nitrogen

Animal excrement is a ubiquitous source of nitrogen. Chapter 5 mentions livestock manure and pet droppings. Other sources of animal waste include fish waste released in the water column, and bird and wildlife droppings released on land. These are not quantified but could represent a sizable load of nitrogen, some of which will be in the form of ammonia. Anecdotally, gatherings of seagulls on the roofs or parking lots of manufacturing facilities have caused runoff to show elevated nitrogen and BOD.

### 6.2.3 Metals

Many urban water bodies have received decades of industrial and municipal discharges that have caused metals to accumulate in the nearby sediments. As the overlying water column becomes cleaner over time, some of those metals may be released from sediments back to the water column.

The hydrologic cycle between ground and surface waters may shift throughout the year as local rainfall causes the water table to rise and fall. During some times of the year, surface water can infiltrate through the bed of the water body and enter shallow groundwater. At other times of the year, if surface flows are low, the groundwater can exfiltrate through the bed of the water body back into the surface water. If a surface water body is located near to a source of groundwater contamination, it is possible that groundwater exfiltration can contribute metals to the surface water.

Neither of these mechanisms lends itself well to data collection. The interchanges undoubtedly occur at certain locations and times, but it is not possible to quantify them.

## 6.3 Uncertainty

The loading estimates shown in Table 17 are based on many assumptions and extrapolations. The estimates start with data that have varying degrees of precision and accuracy.

### 6.3.1 Point Source Uncertainty

The individual facility point source data are generally accurate. They are based on multiple discrete samples from well-defined locations. For TSS and ammonia, where many of the facilities have data values in the DMR data set, the point source loading totals appear to be comprehensive and representative. Presumably all or most of the important dischargers are included in the database, despite the filtering approaches used to exclude some facilities from further evaluation.

When averaging data values at a single facility over time or adding data from multiple facilities to form composite load estimates, one or a few data points much higher than normal can skew the average and maximum for an entire data set. The most obvious example in this study was the single very high TSS value reported, which apparently was a valid measurement. However, in some cases, these are clearly analytical or entry errors.

For the metals, however, only a few facilities reported data. Among the metals, the most data values are available for mercury. However, mercury data are somewhat suspect as previously noted. For example, until the past few years, the mercury analytical method commonly used had a detection level high enough that many samples were reported as <DL. As the more recently issued permits specify mercury monitoring as well as a more precise analytical method, better data are accumulating. Yet confusion between units ( $\mu\text{g/L}$  vs.  $\text{ng/L}$ ) and careless data entry renders some of the newer data invalid, too.

For mercury as well as chromium, vanadium, and selenium, most permits do not require monitoring. At some of the facilities whose permits did require monitoring for metals, a high proportion of the results were reported as <DL. This presents a challenge in accurately characterizing average metals discharges for those facilities.

Even if the metals are present in the discharge, the lack of monitoring data prevents including entries in the database for those facilities.

### **6.3.2 Nonpoint Source Uncertainty**

Because nonpoint sources are not typically regulated through formal programs, no routine, ongoing monitoring data are available. Most often, nonpoint source discharge data are generated through targeted one-time or infrequent research programs. Data are collected from a few sampling points and are extrapolated to make estimates for larger geographic areas.

As Argonne compiled nonpoint source information from the literature, which already had been subject to the original authors' assumptions and extrapolation, an additional layer of assumptions and extrapolation was added. This may compound the uncertainty but is the only practical approach that could be used to generate estimates under the time and budget constraints of the study. To further complicate the estimation process, this report focuses on the Phase I study area—a subset of various other regional studies. For example, if a report characterized nonpoint source releases throughout all of Michigan or the entire Great Lakes region, we had to use only subsets of the nonpoint source loads from those studies.

Modest amounts of nonpoint source data have been collected for some pollutants, but almost no data exist for some of the other pollutants. It was not possible to find sufficient information to develop estimates for chromium, vanadium, or selenium. Some of these chemicals are released from nonpoint sources, but without published data, they could not be quantified.

## Chapter 7 Findings and Conclusions

Both point and nonpoint sources contribute loads of the target pollutants to the Phase I study area in southern Lake Michigan.

### 7.1 Findings

#### 7.1.1 Point Sources

- NPDES program data, particularly the results from the DMRs, are useful in developing point source loadings to the Phase I study area.
- NPDES program managers from Illinois, Indiana, and Michigan provided lists of all municipal and industrial facilities discharging to the southern Lake Michigan region. The lists included 433 point source discharges with permits. In order to limit detailed evaluation to those discharges that had more than modest levels of the target pollutants, various filtering methods were used to remove facilities from the final list. The final combined list from the three states that received detailed evaluation included 80 facilities. This list of facilities composed the loadings database.
- TSS data were readily available from 79 of the 80 facilities in the database.
- Ammonia data were available from 64 of the facilities.
- For the other target pollutants, only limited DMR data were available, such that composite point source loadings were incomplete.
- Data from the permit limits data set and the application data set showed mixed agreement with the DMR data set.
- Because the DMR data set reflects actual monitoring of the discharges during 2007, it is probably the best source of data for estimating point source loadings.
- The TSS average and maximum loading data reflect the very strong influence of a single unusually high TSS discharge during one month.
- Data collected from the TRI system had less relevance because only a few facilities reported releases of the target pollutants to surface waters. The TRI data reported for vanadium compounds was a useful addition to the DMR data.

#### 7.1.2 Nonpoint Sources

- Nonpoint source data are typically generated through targeted one-time or infrequent research programs rather than ongoing regular monitoring programs.
- Nonpoint source data are collected from a few sampling points. The results are extrapolated within the studies to make estimates for larger geographic areas.
- Modest amounts of nonpoint source data have been collected for TSS, ammonia, total nitrogen, and mercury, but almost no data exist for the other pollutants.

### 7.2 Conclusions

- The TSS and mercury loads from nonpoint sources are at least one order of magnitude higher than the point source loads.

- The ammonia loads are higher from point sources, but if the nonpoint total nitrogen load is considered, too, the combined nitrogen input (ammonia plus total nitrogen) from nonpoint sources is much higher.
- Many other sources of pollutants that remain unquantified or poorly quantified (e.g., urban runoff, combined sewer overflows, groundwater exfiltration into surface water bodies, sediment re-release of metals into the overlying water column, excrement from birds and fish) make substantial contributions of the target pollutants.
- The discharges from BP's Whiting refinery are substantial, but are not the highest or the only point source contributor to the Phase I study area. Other large industries and municipal wastewater treatment facilities discharge comparable or higher loads of the target pollutants.

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