Evaluation of Sources

Contaminants in Sediment of Howards Bay
City of Superior, Wisconsin

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Wisconsin Department of Natural Resources

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EXECUTIVE SUMMARY

This source identification study was conducted by the Wisconsin Department of Natural Resources (WDNR) to assess the potential sources that may have caused accumulation of contaminants such as lead (Pb), polycyclic aromatic hydrocarbons (PAHs), and organotin in the sediment of Howards Bay, City of Superior, Wisconsin. This work complements efforts by the Howards Bay project partners: WDNR, U.S. Environmental Protection Agency Great Lakes National Program Office (USEPA GLNPO), U.S. Army Corps of Engineers (USACE), and Fraser Shipyards Inc. (Fraser), on a recently completed focused feasibility study (FFS). The FFS evaluates remedial alternatives to clean up contaminated sediment in the bay for both navigation and environmental protection.

Efforts were made to review the characteristics of contaminants in sediment, and to identify potentially significant sources, including point source dischargers, air deposition, and nonpoint sources. As a result of the review, nonpoint sources and air deposition were identified as the potential significant contributors to the contamination observed in sediment. To predict the contribution of nonpoint sources deposition post remediation, historical loading from these potential sources were evaluated. A mass balance approach was used to analyze and estimate the contaminants in storm water runoff and mass loading to selected areas over the time period of 1940 to 2013. The Source Loading and Management Model for Windows (WinSLAMM) was used to analyze and estimate the contaminants in storm water runoff and mass loading from municipal separated storm sewer system (MS4) to selected areas.

In the analyses, the nonpoint sources were further divided into two categories as 1) background storm water runoff and 2) incidental input. The background storm water runoff was defined as the runoff from MS4, from riparian parcels, and the Interstate Highway (HWY) I-535. The incidental input was assumed to include waste and wastewater associated with accidental spills, marine operation, and illicit connection to the MS4 and illegal discharges. The incidental input sources were often intermittent and hard to identify and quantify; therefore, its significance was evaluated based on the mass balance approach.

Pb was the primary contaminant of concern in the study. PAHs and organotin were not substantially evaluated because they were not detected in the same extent and severity of contamination in the project area as Pb was. Additionally, the source of organotin appeared to be well defined as related to marine paint used on the ocean going vessels and potentially discharge of cooling water by a former power plant in the vicinity of Hughitt Ave. Slip.

Evaluation of selected vertical profiles of contaminants in sediment from five locations of Hughitt Avenue (Ave.) Slip, Cummings Ave. Slip, Fraser Slip, the southeast corner (SE Corner) of the bay, and Area A8 revealed that loading of Pb to the bay peaked in the 1950s – 1970s. The SE Corner was represented by Unit 1 as defined in the FFS report and Area A8 was defined as a portion of the bay, approximately 700 feet (ft) wide and 400 ft long under the Interstate Highway I-535. The contaminants examined also included PAHs and tributyltin which is one of three organotin compounds analyzed and the most often detected.

The distribution of Pb often showed a maximum concentration in the subsurface with a few exceptions. Presence of subsurface maxima at these locations most likely indicates that there were historical sources of Pb input to the bay. Evaluating the profiles along nautical charts revealed that input of Pb to the bay peaked between the 1950s-1970s. Distribution of PAHs and tributyltin in sediment varied from Pb in most locations but was similar at the Cummings Ave Slip.

Monitoring data were reviewed based on WDNR's database and other research studies. The most abundant monitoring data available were Pb in storm water runoff samples collected over the years. An attempt was made to quantify and allocate the contribution of historical background storm water runoff and air deposition to the mass of Pb in sediment. The WinSLAMM model was used to estimate loading of Pb in storm water runoff from the MS4 to selected locations where major MS4 outfalls are located: Cummings Ave. Slip, Fraser Slip, and the SE Corner. Simple proportion and calculation were performed to estimate mass loading of Pb via the MS4 during winter season, from riparian parcels, and air deposition.

Results from the mass balance analyses showed that the background storm water runoff and air deposition combined only accounted for 10% to 26% of Pb present in sediment at Cummings Ave. Slip, Fraser Slip, and the SE Corner. The overwhelming majority or 74% to 90% of Pb present in these locations were attributed to incidental input. The incidental inputs that might have contributed to these areas include, but are not necessarily limited to, historic practices for handling waste and wastewater generated from marine and shipbuilding operations, spills, illicit connection to the City of Superior MS4, and other uncontrolled pathways that were common-place prior to conscious environmental stewardship practices. Conclusions that could be drawn from the results are that the mass loading of Pb from typical storm water runoff alone or combined with direct atmospheric input will not cause Pb concentrations in Howards Bay to be elevated to the levels detected in sediment cores collected from 1993 to 2013.

Using the historical loading information, post remediation concentration of Pb in sediment was estimated to range from 1 milligram per kilogram (mg/kg) to 68 mg/kg in Cummings Ave. Slip, Fraser Slip, and the SE Corner, with assumptions that the background storm water runoff was the only source, new sediment would accumulate to the current configuration, and the sediment would not redistribute from these areas to the rest of the bay. Similarly, PAHs in sediment were predicted to range from 0.3 to 2.3 mg/kg assuming that the storm water runoff from the MS4 will be the only source.

The source identification study concluded that the level of Pb in sediment will neither return to current condition nor the levels of concern following remediation. Moreover, WDNR believes the probability of sediment being recontaminated to present levels by nonpoint sources is low as the City of Superior, industries, and businesses are implementing nonpoint source management regulations and programs. Adopting best management practices will further reduce spills and other incidental releases of waste and wastewater. This trend demonstrated by Pb also applies to PAHs and organotin. Particularly, the major source of organotin to the marine environment will be controlled due to complete phase out since 2008. Sediment quality and subsequently water quality in Howards Bay, is projected to improve after the sediment remediation project is completed.

1. INTRODUCTION

Howards Bay is located in the City of Superior, Douglas County, in northwest Wisconsin. Sediment in the bay is contaminated with heavy metals such as lead (Pb) and organics such as polycyclic aromatic hydrocarbons (PAHs) and organotin based on data collected since the 1990s. A focused feasibility study (FFS) was completed recently by the Howards Bay project partners**:** WDNR, U.S. Environmental Protection Agency Great Lakes National Program Office (USEPA GLNPO), U.S. Army Corps of Engineers (USACE), and Fraser Shipyards Inc. (Fraser). Fig.1 illustrates the boundary of the project area. The FFS proposed to remove and/or cover contaminated sediment in the management units shown in Fig. 2. Upon completion of the design phase, implementation of the project will be carried out as a collaborative public-private venture under the Great Lakes Legacy Act (GLLA) funding mechanism.

The GLLA requires that before a project can proceed to implementation, the non-federal sponsors need to conduct a source identification study to ensure that the project area will not be recontaminated by existing known sources after cleanup. WDNR, as one of the non-federal sponsors, undertook the source identification study to address said GLLA requirements. This document summarizes WDNR's effort on identifying potential sources, assessing quantity of the input from the identified sources, and when applicable predicting sediment quality post remediation. To complement the FFS, this study primarily focuses on evaluation of potential sources that contributed Pb to the bay. PAHs and organotin are not substantially evaluated as a part of this study because both groups of contaminants are not appreciably elevated in a large portion of the bay, and the source of the organotin appeared to be well defined as related to marine paint used on the ocean going vessels and potentially discharge of cooling water by a former power plant in the vicinity of Hughitt Ave. Slip, rendering a detailed analysis, such as the one undertaken for Pb, unnecessary. Also, it is important to note that the purpose of this document is not to direct sources of contamination to a particular responsible party(s), but to provide a baseline assessment of the potential for future recontamination following remediation.

2. IDENTIFICATION OF SOURCES

2.1 General Site Information

The project area of Howards Bay is approximately 300 acres, situated in the Duluth-Superior Harbor, which is part of the St. Louis River Estuary. Throughout historical development, Howards Bay became a major industrial area in the City of Superior [WDNR and MPCA, 1992]. Back in the late 1800s, "where sail meets rail" was the slogan of the City of Superior which suggested that Howards Bay provided opportunities for industry and commerce. As a consequence of industrial development and commercial activities, contaminants have accumulated in the bay.

A review of the available nautical charts available on NOAA's website (http://www.nauticalcharts.noaa.gov/csdl/ctp/abstract.htm) indicates that the bay and adjacent land have been home to a series of shipyards and other industrial operations for over 100 years. The configuration of the bay, particularly the south side, as shown on nautical charts (Appendix A), has changed greatly in order to accommodate needs for industrial and business operations over the years. The photo in Fig. 3 demonstrates how busy the embayment was in the 1970s. In

Fig. 1 Howards Bas sediment remediation project area

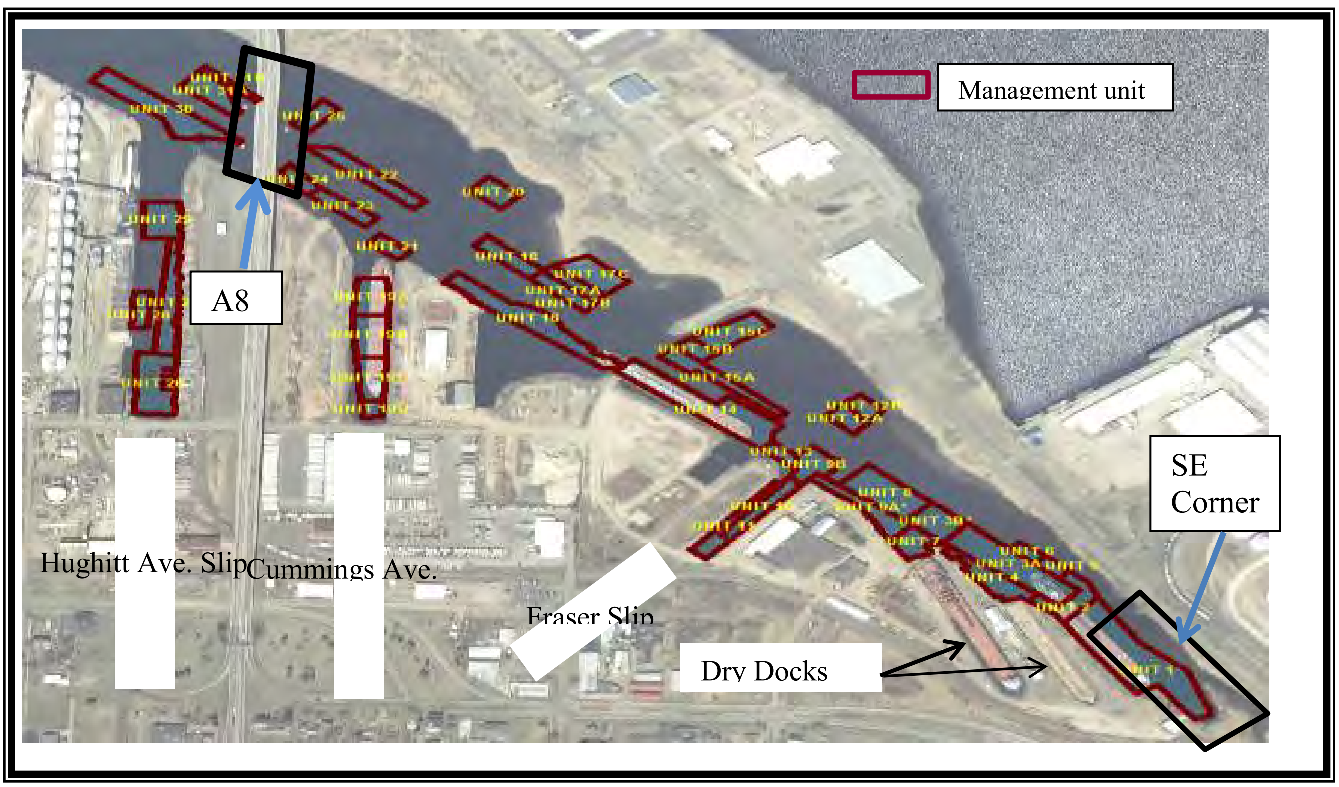
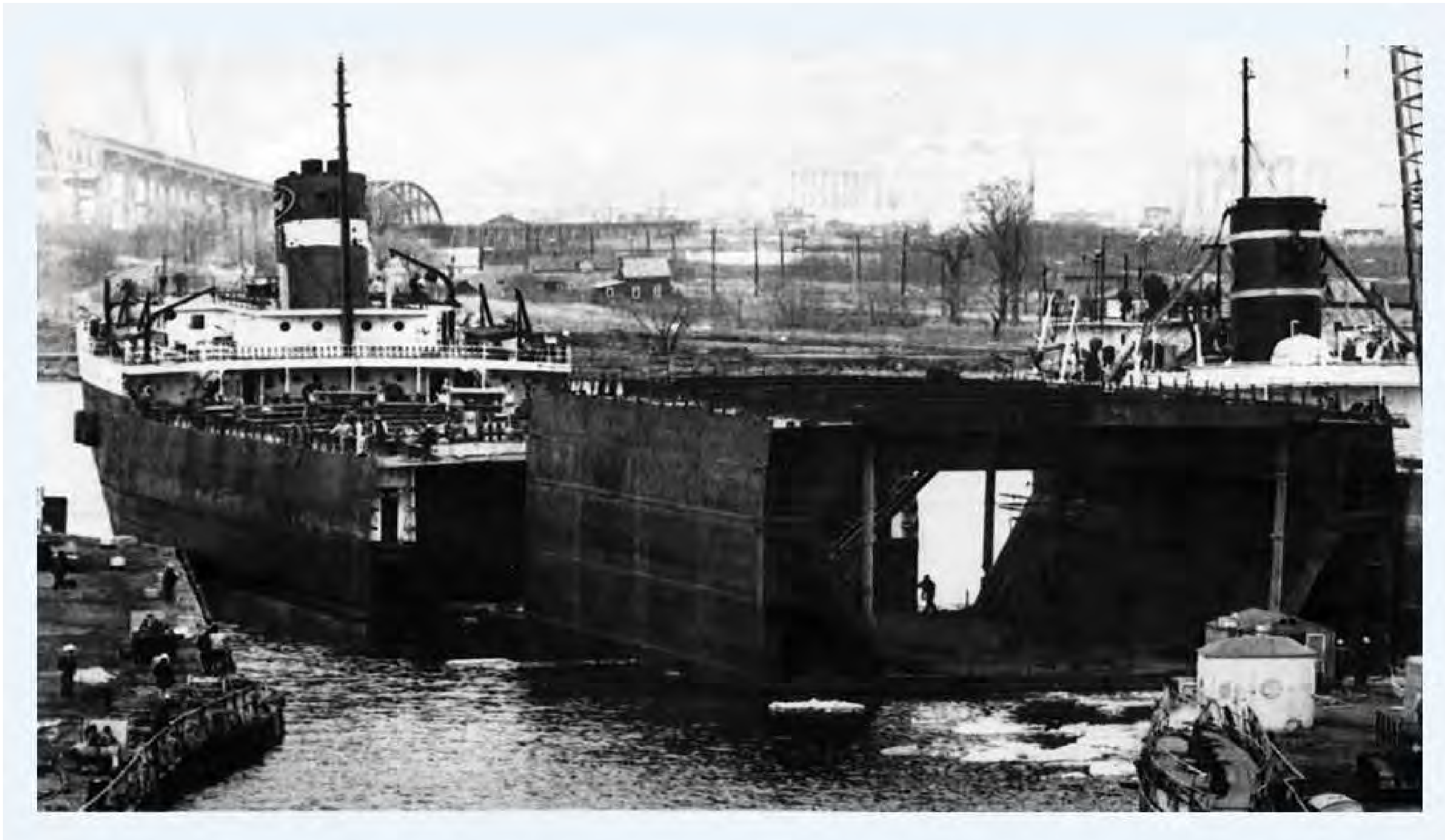


Fig. 2 Preliminary conceptual sediment management units (Area A8 is specifically defined as a portion of the bay for this study. The rest of the units is adopted from the FFS, ARCADIS, 2015. Note that the extent of the management units is subject to modification in the design phase of the project.)



Source:http://www.boatnerd.com/news/newsthumbsb/images-11-1/Ford,-William-Clay-lengthen1-AP-1979.jpg

Fig. 3 Example of marine operation in Howards Bay in 1979

the past, ship building and maintenance were the major industrial land uses in the bay area along with sawmills, wharves, and grain elevators. Although a number of shipyards had operations on the southeast end of Howards Bay, the major business today is Fraser Shipyards, Inc. which has been in operation since 1977, when Fraser Nelson Shipbuilding, a subsidiary of Reuben Johnson & Son, Inc., purchased the facility from the American Steel Barge Company. Fraser primarily performs ship repairs and maintenance, and most of their work is done during the winter months.

Currently along the south shore of the bay there are major ship slips including Hughitt Ave. Slip, Cummings Ave. Slip, Fraser Slip, and two dry docks as shown in Fig. 2. Cummings Ave. Slip and Fraser Slip are mainly used by Fraser for shipbuilding and maintenance. Sometimes, the slips are also used for docking smaller local law enforcement boats. Hughitt Ave. Slip is used by Central Harvest State (CHS) for loading and unloading ships at the grain elevator and by Sivertson Fisheries for docking fishing boats (ARCADIS, 2015). Fig. 4 illustrates typical marine operations in the bay area at present time.

To accommodate shipping needs, the USACE maintains a federal channel right off the slips. Historically, the channel depth was authorized for 21 ft below Lake Superior low water datum (LWD) IGLD85. Sometime in the early 1960s, the authorized depth changed to 27 ft below LWD. The width of the navigation channel ranges from 175 ft at the southeast end, to 450 ft near the opening of the bay. Based on a review of the USACE dredging records, some stretches of the channel might have been dredged to 30 ft below LWD by 1963, which was the deepest in the available records since 1915. After the 1980s, dredging in Howards Bay became less frequent and limited to specific local areas. The most recent limited dredging occurred in 1997 and 2011 near Hughitt Ave. Slip. The majority of the bay, east of the Interstate Highway (HWY) I-535 Bridge (Fig. 5), has not been dredged since 1981.

The Interstate HWY I-535 Bridge connects the two port cities of Superior and Duluth (Fig. 5). Construction of the bridge was completed in 1961 [WI and MN, 1961]. A total of 1.2 linear miles out of the 2.8 mile long highway which contains the bridge is on the Wisconsin side [USDOT, 2002]. The traffic volume was estimated at 29,500 vehicles per day in 2006 [Minnesota DOT, 2012].

2.2 Potential Sources

Waste, wastewater, and storm water from industrial, commercial, and residential areas can potentially discharge into the bay directly or via collection systems. Contaminants emitted into the air can fall back to land as dry fall out or precipitation and then enter water bodies (indirect deposition) or they can directly enter surface water. For the convenience of the mass balance analyses, these potential sources were divided into three major categories as illustrated in Fig. 6. In general, these categories include waste and wastewater discharge point sources, nonpoint sources, and atmospheric deposition.

Given the complexity of nonpoint sources, they were further categorized into two subcategories, one being the background storm water runoff, including runoff from the municipal separated storm sewer system (MS4) discharges, direct storm water runoff from riparian parcels and the

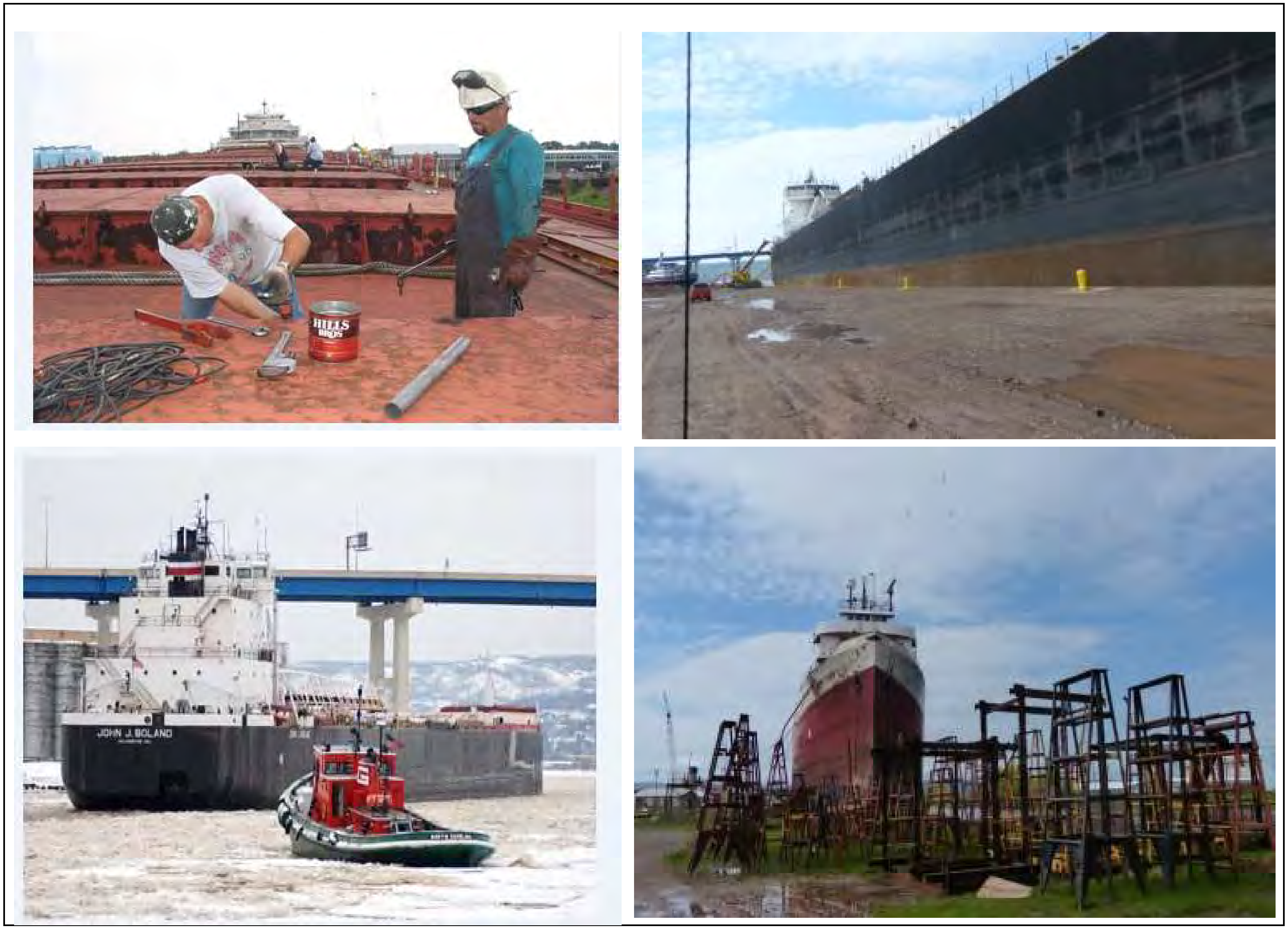
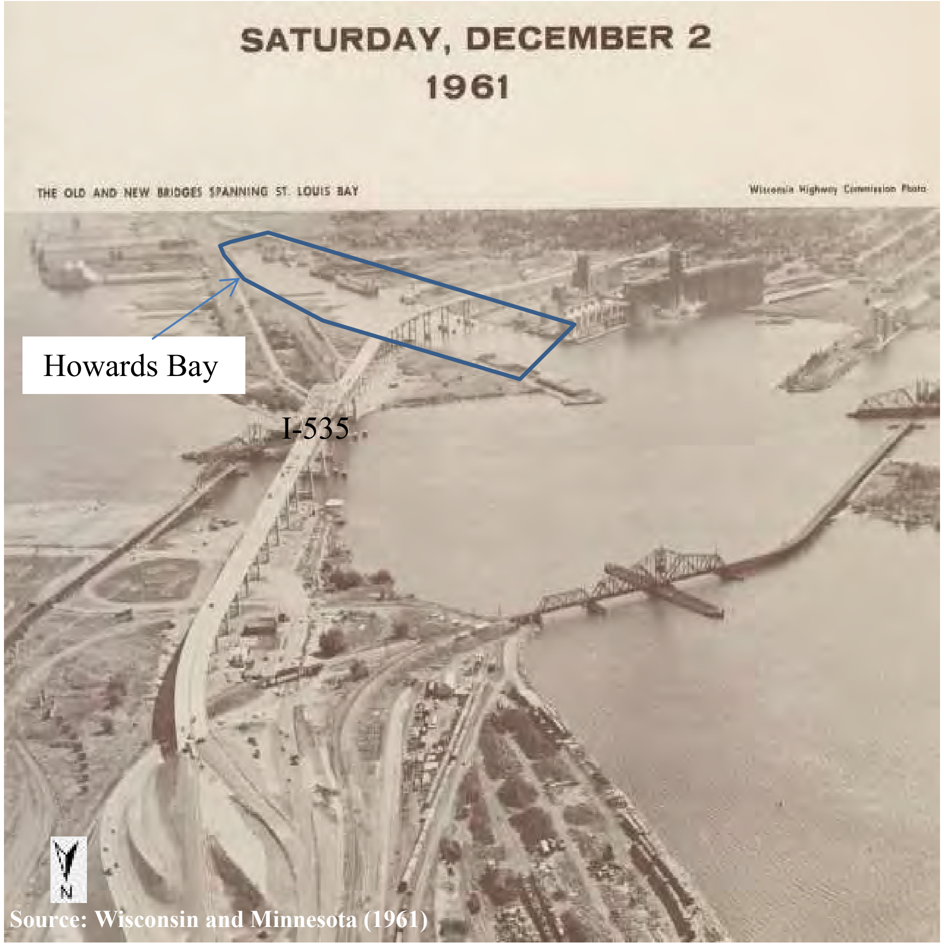


Fig. 4 Examples of recent typical land use and marine operation in the bay area



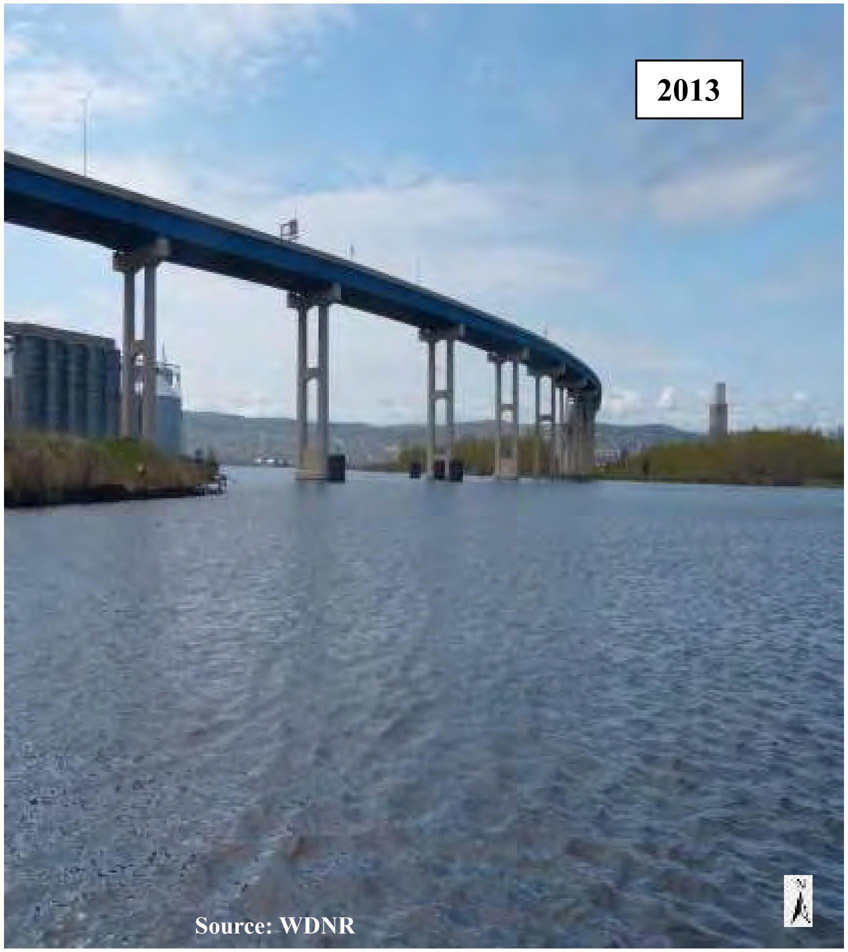


Fig. 5 Interstate Highway I-535 Bridge Crossing Howards Bay

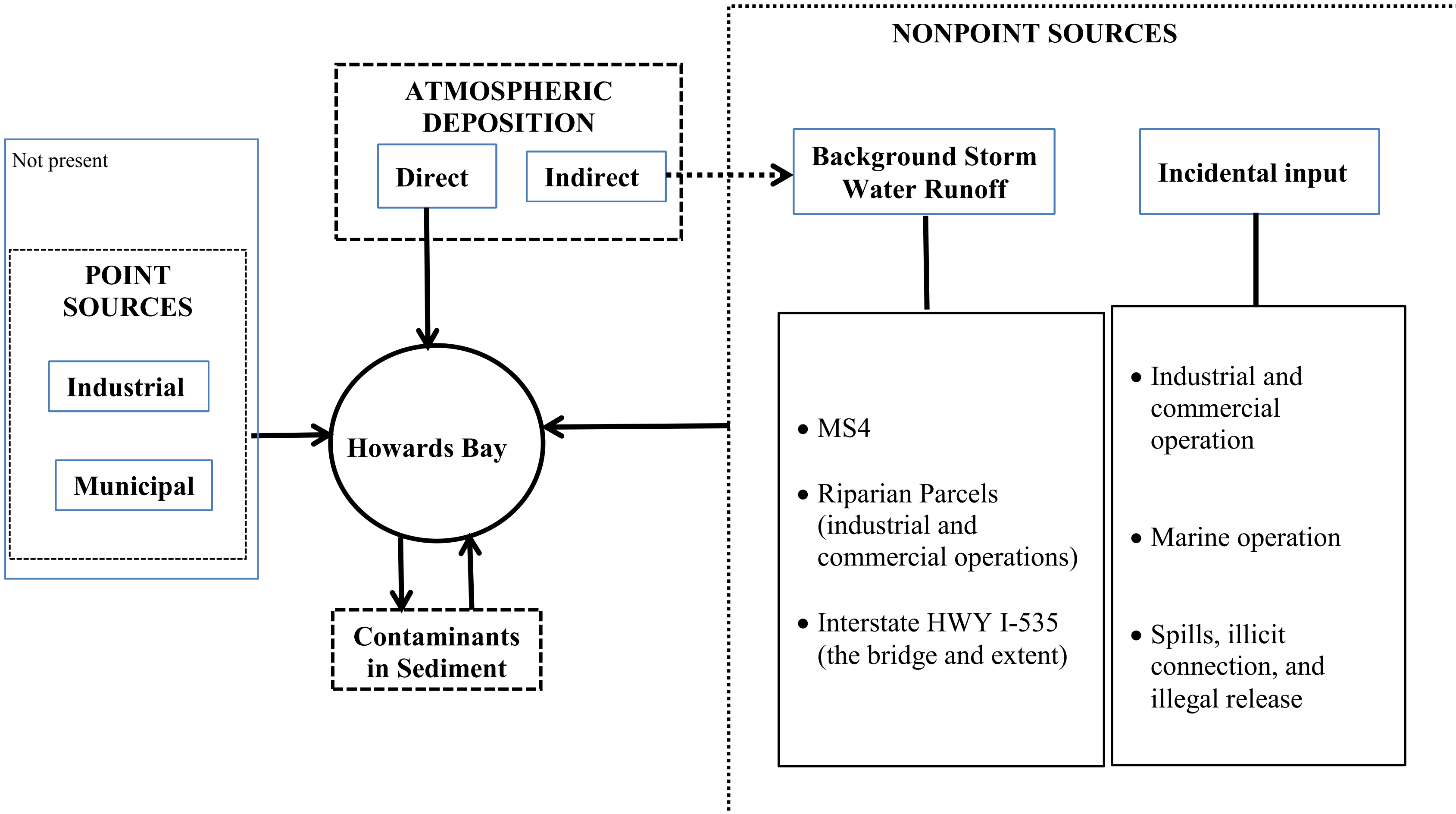


Fig. 6 Potential sources of contaminants to Howards Bay

Interstate HWY I-535, and indirect atmospheric deposition. These sources are continuous on an annual basis, so the contribution of contaminants to the bay is a function of precipitation and concentration of contaminants in the storm runoff. The other subcategory is defined as incidental input, including waste and wastewater input from industrial and marine operations on riparian parcels, spills, and illicit discharges, as well as illegal releases. In the past, due to a lack of understanding of the harm nonpoint sources pose to the environment and before nonpoint source related regulation was promulgated, these nonpoint sources might have discharged into the bay without best management practices. If not managed these nonpoint sources could contribute to recontamination of sediment after remediation. Unfortunately these incidental input sources are often unknown and hard to identify although efforts have been carried out such as identifying illicit connection to the MS4 [Field *et al.*,1994, Brown *et al.*,2004].

2.2.1 Point Sources

Under the Clean Water Act (CWA), municipalities and industries are required to obtain a point source permit to discharge industrial and domestic wastewater to adjacent water bodies. A review of WDNR's Wisconsin Pollution Discharge Elimination System (WPDES) permit [WDNR, 2015a] records revealed no municipal or industrial point source dischargers within the watershed of the Howards Bay project area, at present time. A former power generating station was operated in the area during an unknown period of time, prior to CWA regulation. With the unknown nature, the waste and wastewater discharged from industrial and business operations historically were considered incidental input, not point source discharges. As a result, point sources were not considered to be a significant source of the contamination detected in the sediment, nor potential recontamination sources following remediation. Therefore, no further evaluation of point sources was conducted as a part of this study.

2.2.2 Nonpoint Sources and Nonpoint Source Control Programs

Nonpoint sources were reviewed with two categories: background stormwater runoff and incidental input as illustrated in Fig. 6. Since the 1990s, various programs have been in place to control nonpoint sources in Wisconsin. Currently, Wisconsin manages nonpoint sources with both regulatory and non-regulatory approaches. The regulatory approach, promulgated in 1994, requires landowners, industries, large agricultural operations, and municipalities to obtain storm water permits under the state administrative code Chapter NR 216 in order to reduce erosion and the loading of contaminants to water bodies. A non-regulatory approach is mainly applied to agricultural practices. Since Howards Bay is located in a highly developed urban area, it receives regulated nonpoint source discharges from the City of Superior's MS4 and from industries. Spill laws and best management pratices have also been in place to prevent incidental input as defined earlier.

2.2.2.1 Background Stormwater Runoff

MS4 discharge from the City of Superior

The City of Superior holds a general MS4 discharge permit. The permit allows the city to discharge storm water, including rainfall and snowmelt, collected from construction sites, lawns, parking lots, roofs, and roads where the MS4 covers, to the outfalls. As shown in Fig.7, three major outfalls discharge storm water runoff to Howards Bay at Cummings Ave. Slip (outfall OT010150), Fraser Slip (outfall OT010066), and the SE Corner of the bay (outfall OT010307).

Under the MS4 permit, the City of Superior is required to implement and report annually on the following efforts:

- Public Education and Outreach
- Public Involvement and Participation
- Illicit Discharge Detection and Elimination
- Construction Site Pollutant Control
- Post-Construction Storm Water Management
- Pollution Prevention Practices for the Municipality
- Storm Sewer System Maps
- Documentation of Impaired Waters

The 2014 annual report that was completed on March 31, 2015 (Appendix B) described implementation actions and plans for each element listed above. The status of measurable goals and the compliance schedule were also documented. As part of the permit requirement, the city has collected runoff samples from these major outfalls in 2013 and 2014. The data will be discussed in Section 4.

Industrial storm water runoff and erosion from construction sites

Since the 1990s, runoff from industrial and construction sites has been required to be controlled by the best management practices (BMP) under the regulatory program. Wisconsin DNR maintains a series of databases [WDNR, 2015a] for tracking general and specific storm water discharge permits issued to industrial activities inclduing land disturbing construction activities (i.e., clearing and grubbing, grading, excavating). The City of Superior also documents this information in its annual report. As described in Appendix B, there are currently around 11 industrial facilities that hold a WDNR storm water permit (Figure 2.8.4 of Appendix B) within the watershed. Therefore these industries potentially discharge runoff from their parcels directly to Howards Bay. Industries holding the permits include Fraser Shipyards, Genesis Attachments, Hallett Dock Company, Halvor Lines Inc., Jeff Foster Trucking Inc., Northern Engineers Works, OSI Environmental Inc., Stella-Jones Corp, Valley Cartage & Warehousing , and Woodline Manufacturing. Additionaly, although CHS does not hold an industrial storm water permit, a portion of runoff from its site could potentailly drain to Hughitt Ave. Slip. Among these 11 permittees, Fraser owns the largest land and is in the closest proximity to the bay, as shown in Fig. 8. A photo showing on-going discharge from the Fraser lot is also illustrated as part of Fig. 8. While it is not clearly shown on Fig 7, a portion of the shipyard property drains through the MS4 outfall to Fraser Slip according to the Stormwater Pollution Prevention Plan for the shipyard (ARCADIS 2015b). Regardless of where the parcels drain to, regulation requires the industries to implement BMP to minimize storm water runoff.

The BMP requirements also apply to construction sites. Based on the annual report (Appendix B), the City of Superior approved and issued 50 construction permits in 2014. These construction sites may include those on riparian properties in addition to activities further up the watershed.

Fig. 7 Drainage area of the MS4 and location of major outfalls in Howards Bay (City of Superior, 2014)

Direct runoff observed along the south east wall
of Fraser Slip on September 9, 2013

Fig. 8 Direct runoff riparian parcels and storm sewer outfall drainage areas (the photo was taken by WDNR)

Direct runoff from riparian parcels

Riparian parcels may have storm water runoff from their lots flowing directly into the bay as Fig. 8 indicates. Storm water from some of the riparian parcels is covered under the storm water permit program. As discussed previously, a portion of the runoff from the Fraser Shipyard property is connected to the MS4.

Storm water runoff from the Interstate HWY I-535

Storm water can drain from the Interstate HWY I-535 and the bridge into the bay, both directly and indirectly. Characteristics of the runoff generated from the highway and bridge are related to many factors, including the design of the highway, daily traffic flow, type of materials used, vehicle fuel types, and etc. Two particular factors, traffic flow and Pb in fuel, are of interest for this source identification study for Pb. As shown in Fig. 9, the number of vehicles registered in use nationwide increased steadily since 1940 at a rate of approximately 3.5 million per year, until 2005 when it stabilized. In 1940, there were about 32 million vehicles registered. By 2005 the number had increased to 250 million. It can be assumed that the cities of Superior and Duluth followed a similar increasing pattern of the number of registered vehicles. Opposite to the increase of registered vehicles, the lead added to gasoline has decreased since the 1980s due to various federal and state programs. According to the USEPA [1973, 1985a, 1996], a gradual reduction of lead in gasoline started in the early 1970s. Lead concentration in “regular” gasoline decreased from 4 grams per gallon (g/gal) in the 1970s to 0.5 g/gal in 1985, and 0.1 g/gal in 1986. By December 31, 1995, leaded gasoline was completely phased out. This is an important factor in evaluating Pb in storm water runoff and atmospheric deposition.

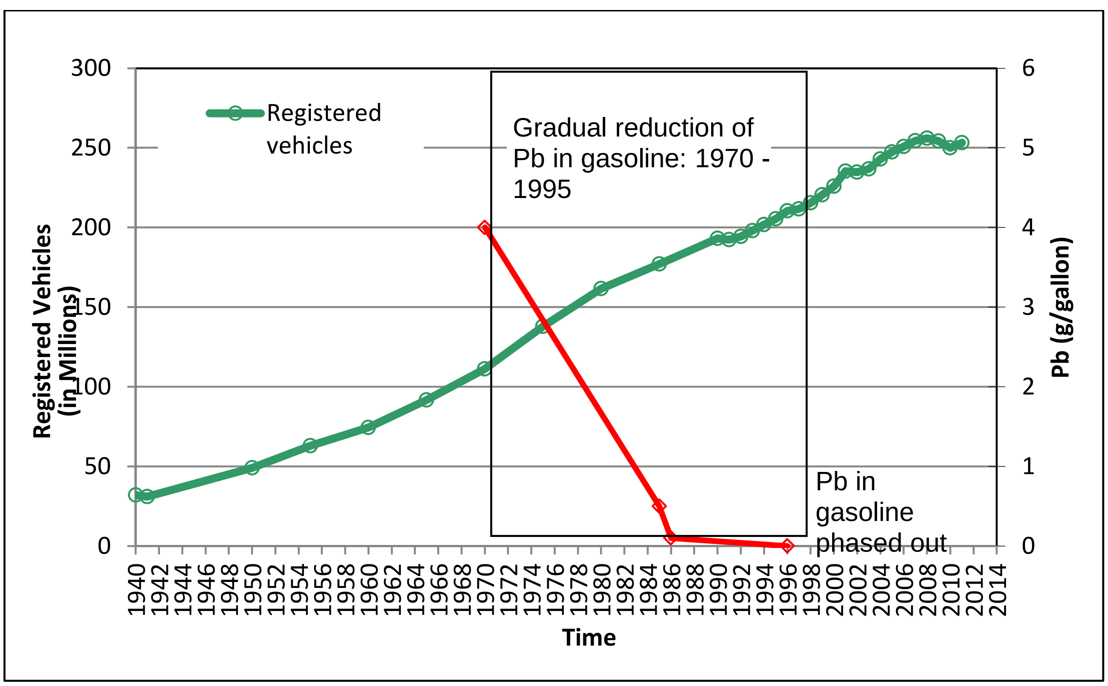


Fig. 9 Number of vehicles registered in the US from 1940 to 2012 (USDOT 2015, USEPA, 1973, 1985b, 1996)

2.2.2.2 Incidental Input

Waste and wasterwater from marine Operations

Historically, marine and marine related operations may have discharged waste and wastewater directly to Howards Bay. For instance, in 1993, hazardous waste staff from the WDNR inspected Fraser Shipyards to determine compliance with applicable regulations. The inspection revealed major alleged violations of hazardous waste rules, including improper storage and disposal of waste oils, waste paints, and solvents. Fraser has undertaken an evaluation of 14 areas of concern (AOCs) identified during the inspection and located on the Fraser property. The 1993 inspection indicated that paint chips mixed with sandblasting grit generated during site activities appeared to be entering Howards Bay from the drydocks at Fraser Shipyards. As part of its business, Fraser repainted ships. Old paint was removed by sandblasting while ships were in drydock, and the grit and paint chips were allowed to settle to the bottom of the drydock. When the drydock was flooded to allow for ships to depart, the grit and paint chips were suspended in the surface water column and then deposited in the sediment of Howards Bay. Sampling of the grit from Drydock 1, the clay base of the drydock, and the sediment in Howards Bay adjacent to the drydock has all revealed elevated lead concentrations. Continuous disturbance caused by shipping and other processes may spread the materials in the bay. As part of solid waste and Spill law regulations, cleanup of contaminated AOCs has been completed, with the exception of AOC #14, the contaminated sediment area within Howards Bay.

Other industries, such as CHS, may also have operations that contributed contaminants to the bay. WDNR has sent out letters seeking information regarding waste and wastewater released into the bay. If problems are identified in the future, corrective actions will be required.

A former power generating station was located within the watershed and the remnants of its intake structure can still be found at the head end of Hughitt Slip. The former power plant was also connected to an outfall in Cummings Slip and may also have had a discharge structure in Tower Bay slip which is located outside this project area.

Spills, illicit discharge, and the illegal release of waste and wastewater

Inevitably, spills and accidental release of chemicals, waste and wastewater can happen during industrial and business operations. Wisconsin DNR keeps record of spill incidents in the Bureau of Remediation and Redevelopment Tracking System (BRRTS). A search of the database did not reveal any major incidents in the watershed after the 1990s. However, it is possible that incidents occurred that were not reported to DNR and are not on the BRRTS database.

Sometimes, waste and wastewater associated with industrial activities on non-riparian properties can enter the bay due to illicit connection to the MS4. For instance, before 2008, recurring oil slicks appeared in Cummings Ave. Slip. The source of these slicks was traced back to a former Superior Water, Light and Power building located a few blocks south of the slip. The building is now privately owned and houses a heavy truck repair and equipment rental facility. As best as can be determined, a fuel oil tank and 55-gallon drum storing waste oil in the building's basement would periodically tip over and spill their contents due to flooding of the basement. The floodwaters containing spilled waste oil were pumped into City of Superior storm sewer lines via illicit storm sewer connections under the building, and ultimately discharged to Howards Bay via the outfall in Cummings Slip. The City of Superior and WDNR staff worked with the building owner to address the conditions leading to these releases, including disconnecting and capping illegal connections and directing facility wastewater to the City of Superior's sanitary sewer lines. The building owner completed this work in the fall of 2008, effectively eliminating the potential for additional releases from this source. With the implementation of an illicit discharge detection and elimination program by the City of Superior under the MS4 storm water regulations, such illegal discharges will be reduced, if not eliminated, in the future.

2.2.3 Atmospheric Deposition

A number of studies have been conducted regarding air pollution and the fallout of contaminants down to the ground and aquatic systems [Winchester and Nifong,1971; Eisenreich *et. al*., 1986; Alexander *et al.*, 1988; Rasmussen P., 1998; Klein, 1975; EC and USEPA, 2000, 2005, 2008; USEPA 1981, 1985, 1994, 1997, 2000; Hoff *et al*.1996; and Laneky *et al*.1998.]. With regards to Pb, before unleaded gasoline was introduced, vehicle emissions were the primary source of airborne lead. The USEPA, state, tribal and local government agencies tracked air quality trends for lead using data from a network of monitors. The air quality monitoring network measures concentrations of lead throughout the country and includes a station at Duluth, Minnesota. Nationally, average lead concentration in the air has decreased dramatically since the 1980s. The concentration decreased by 92% between 1980 and 2013 as shown in Fig. 10. After 2002, Pb was not detected at the Duluth, MN site [http://www.epa.gov/airtrends/lead.html]. During the past decade, no areas in Wisconsin have had levels of lead that exceeded the National Ambient Air Quality Standard (NAAQS) of 0.15 ug/m^3[WDNR, 2015b].

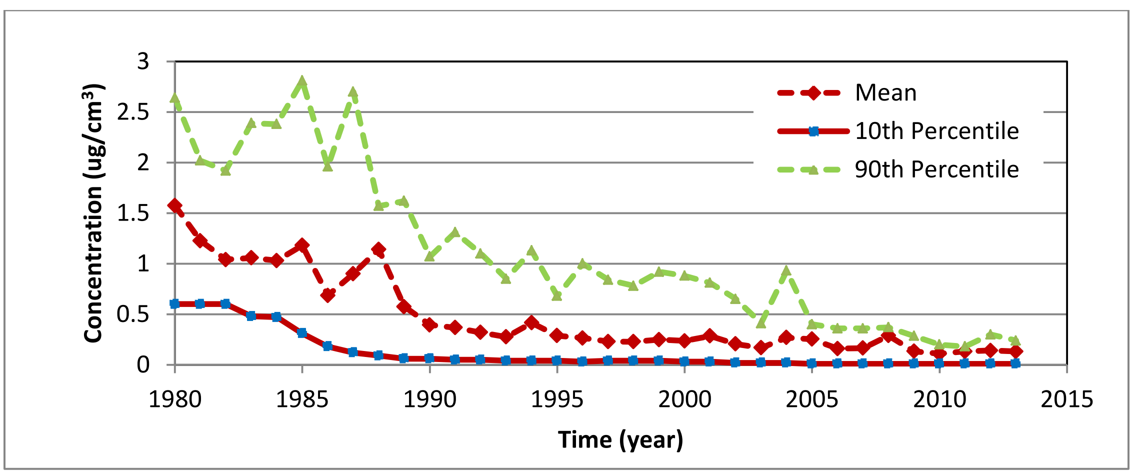


Fig.10 Concentration of Pb in the air (based on annual maximum 3-month average at 12 sites, USEPA: http://www.epa.gov/airtrends/lead.html**)**

Although the emission of Pb and other contaminants from automobiles have decreased significantly, atmospheric deposition can still be a potential source of contaminants in the future. Analyses of the contribution from atmospheric deposition will be discussed in Section 4.

3. SOURCE EVALUATION BASED ON DISTRIBUTION OF CONTAMINANTS IN SEDIMENT

To some extent, the lateral and vertical distribution of contaminants can serve as markers to help understand sources and the temporal record of loading history from sources, assuming that the deposition patterns of sediment have not been altered significantly due to in-situ dynamic processes and human activities. This section will provide source evaluation based on the concentrations of Pb, PAHs, and tributyltin in sediment collected between 2007 and 2013from five selected locations including Hughitt Ave. Slip, Cummings Ave. Slip., Fraser Slip, the SE Corner (Unit 1), and Area A8 as shown in Fig. 2. The five locations were selected because high concentrations of contaminants were detected and multiple sources may have contributed contamination to the sediment. In addition, except for some parts of Hughitt Ave. Slip and Area A8, sediment has not been dredged frequently; therefore, distribution of contaminants in these areas may provide helpful records for analyzing potential sources and temporal contamination records.

In general, within the project area, Pb was detected in higher concentrations in the Cummings Ave Slip, Fraser Slip, and the SE Corner of the bay (Unit 1) compared to the rest of the bay. A maximum concentration of 1,145 mg/kg was detected in the SE Corner. Sediment samples collected from the north side of the navigation channel showed fairly low level of contaminants. The concentration of Pb in sediment from the navigation channel showed an increasing trend from west to southeast and from the center of the channel to near the slips. This overall spatial distribution pattern implies that 1) there were no significant direct input sources of Pb along the north side of the bay, 2) soft sediment does not accumulate outside of the channel on the north side of the bay, and 3) transport of sediment from outside of the channel may have caused contamination in the navigation channel.

Similar spatial distribution patterns were observed among sediment samples analyzed for PAHs and tributyltin. These two parameters were analyzed for all samples collected in 2007 and 2010 but only for selected samples in 2013. Maximum concentrations were 68 mg/kg and 270 micrograms per kilogram (ug/kg) for PAHs and tributyltin, respectively. The highest PAH concentration was observed in sediment from Cummings Ave. Slip, while the highest tributyltin was in a sample from Hughitt Ave. Slip. Relatively low concentrations of PAHs and tributyltin were observed outside of the navigation channel on the north side of the bay. Localized sources such as discharges from illicit connections to the MS4 by the heavy truck repair and equipment rental facility discussed earlier, could have contributed PAHs to Cummings Ave. Slip. High tributyltin observed in Hughitt Ave. Slip might also be linked to localized sources, including but not limited to its use in antifouling paint on commercial and recreational vessels and in heat exchange tubes.

Vertical distributions of contaminants in the sediment were examined by plotting concentrations of Pb, PAHs, and tributyltin against sediment elevation relative to International Great Lakes Datum of 1985 (IGLD85). The elevation was also cross referenced against historical nautical charts for a potential sedimentation date assignment, when applicable. Although the information on the charts may carry high uncertainties, relative comparison on a scale of decades is useful for the purpose of estimating sedimentation rates and general source identification, particularly when the information can be further verified by cross reference to detailed bathymetric survey maps from the USACE. A series of bathymetric maps provided by the USACE showed that the navigation channel was dredged to its deepest depth in 1963, which may affect the distribution of sediment deposited near the channel.

3.1 Sediment Cores from Hughitt Ave. Slip

Fig. 11 shows the concentrations of Pb, PAHs, and tributyltin in sediment vs. the bottom of each sediment segment of cores from Hughitt Ave. Slip. The sediment core locations are also displayed in the figure. No soft sediment materials were retrieved from HB13-44X.

These distribution plots demonstrate that concentrations are higher along the east side of the slip, where it is shallower than the west side. Sediment cores collected from the west side, such as Cores HB13-35A, HB10-1-20, and HB13-37A, contain much lower concentration of contaminants. Slightly elevated PAHs were observed in surface sediment in the deeper west side of the slip. Near the south side shore, sediment core HB10-1-28 showed exceptionally high levels of tributyltin in surface sediment compared to that in the rest of the bay. The maximum tributyltin observed in surface sediment may imply an ongoing source, or that the sediment has been constantly disturbed. Further investigation is warranted. WDNR's Remediation and Redevelopment Program has issued letters to adjacent property owners along Hughitt Ave. Slip for additional information regarding sources. Future corrective action will be required if an active source is identified. However, an existing active source is predicted to be less likely.

3.2 Sediment Cores from Cummings Ave. Slip

Fig. 12 shows profiles of Pb, PAHs, and tributyltin in sediment cores from Cummings Ave. Slip. Some significant observations on the distribution patterns can be summarized as follows:

- The change of morphology over the years as shown by nautical charts in Fig. A-3, A-5, and A-10 (Appendix A) has affected the distribution pattern. Less contaminated sediment has accumulated on west side (Cores HB10-1-21, HB10-1-24, and HB13-43) and close to the opening of the slip (Core HB13-42) perhaps due to dredging and shipping activities.
- Because Pb concentration is still greater than 80 mg/kg in the bottom segment, it suggests that Cores HB10-1-29 and HB13-45 might have not reached native material, or native material underlies the bottom segment.
- Bathymetric data presented on the nautical charts show that at Core HB13-42, sediment thickness changed from approximately 15 ft (Fig A-3) to 13 ft (Fig. A-4 and -5), then to 14 ft (Fig. A-9). The change indicates that 2 ft of soft sediment was accumulated between 1946 and 1961, but somehow 1 ft of sediment left the area by 2007. At this core location the native material is potentially at an elevation of 585 ft based on the field record. The elevation was cross examined with the data on the 1946 Chart (Fig. A-3).
- The assignment of native materials is supported by the significant decrease of Pb concentration from the upper segment to the bottom of the core.
- Similarly at core location HB13-45, approximately 2 ft of soft sediment was deposited in the area between 1946 and 1961. The thickness of soft sediment has remained almost unchanged at this location since 1961, potentially due to lack of disturbance. The highest

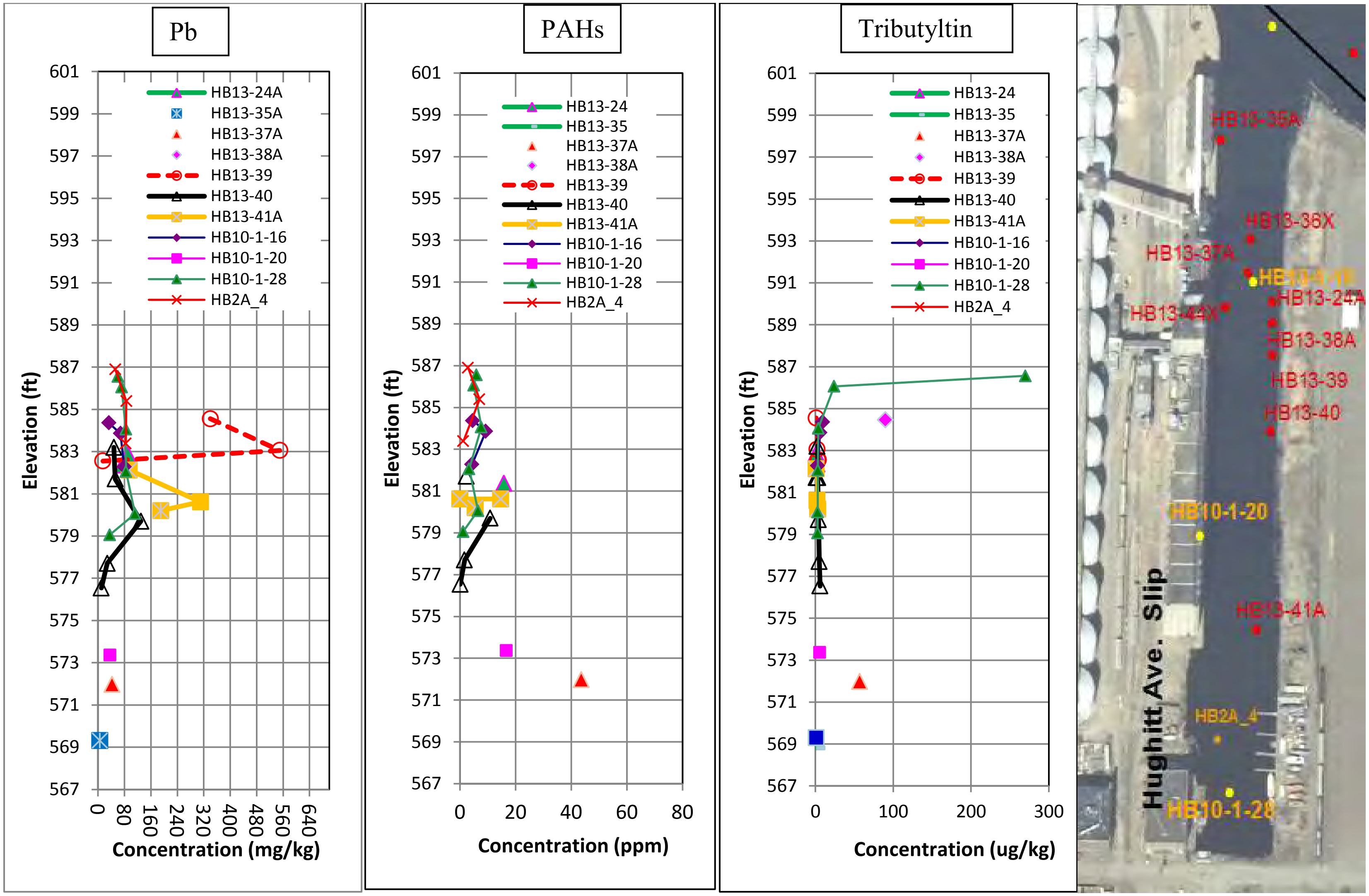


Fig. 11 Vertical profiles of Pb, PAHs, and tributyltin in sediment from Hughitt Ave. Slip

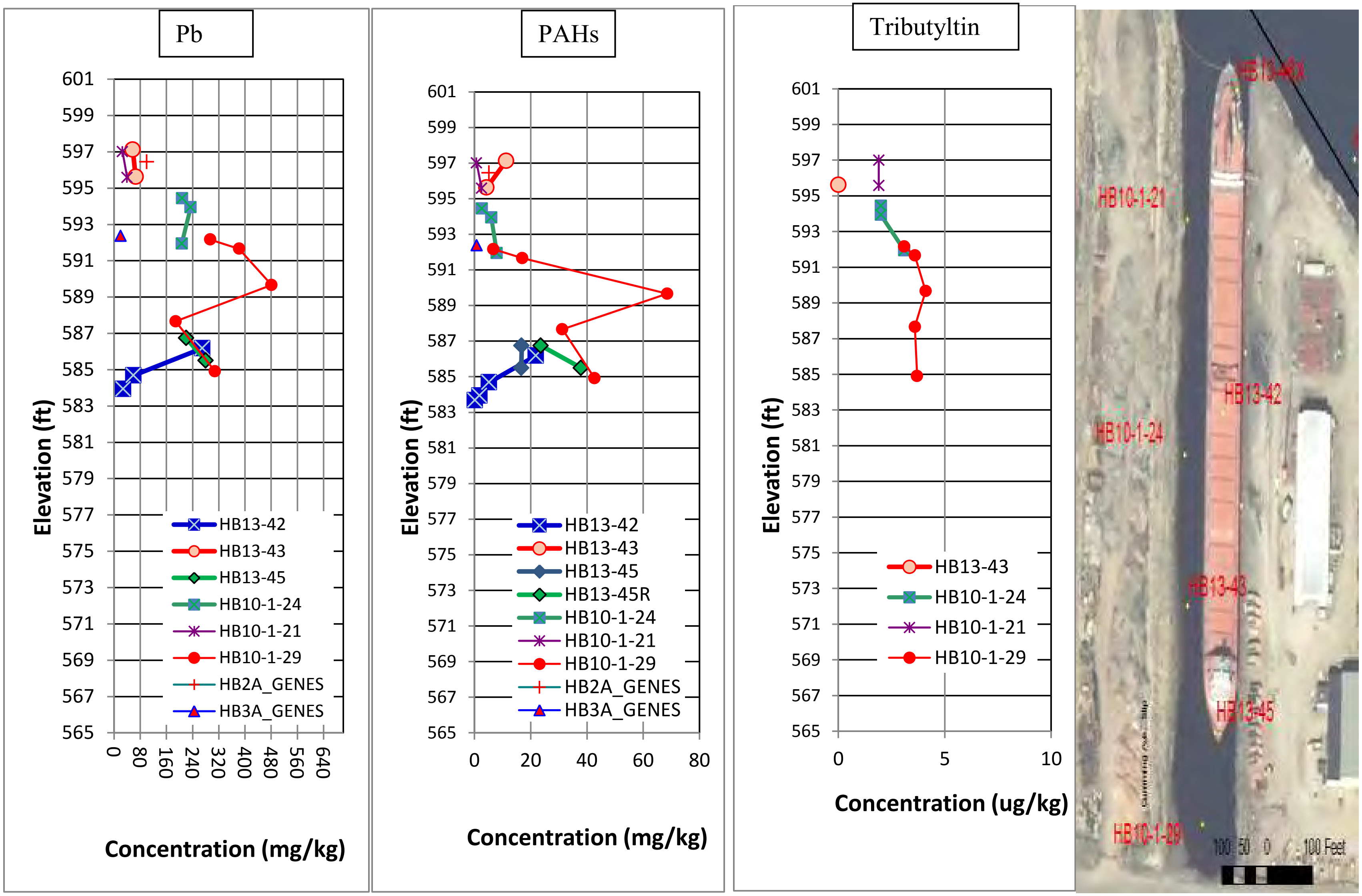


Fig. 12 Vertical profiles of Pb, PAHs, and tributyltin in sediment from Cummings Ave. Slip

concentration of Pb (480 mg/kg) is present in Core HB-10-29 at an elevation of 589 to590 ft. When comparing the nautical charts dated 1946 and 1961, approximately 6 ft of soft sediment was deposited at this location during this 15-year period. This suggests that the majority of sediment in this location, including the segment with the maximum concentration was deposited before the 1960s, because a total of 8 ft sediment was retrieved.

- Between elevation of 587 and 585 ft (IGLD85), the concentration of Pb is similar in sediment Cores HB10-1-29, HB13-42, and HB13-45, an indication of potentially similar sources. Distribution of Pb at Core HB13-42 may help infer that concentrations would drop off significantly in sediment deeper than 585 ft at the areas where the other two cores were collected but without accompanying samples.
- The PAH profiles showed similar patterns as observed for Pb, an implication that similar sources might have contributed both Pb and PAHs. Tributyltin was analyzed only for selected cores. Relatively higher concentration was observed at the elevation between 585 and 592 ft at location HB10-1-29.

3.3 Sediment Cores from Fraser Slip

Fig. 13 shows profiles of Pb, PAHs, and tributyltin in sediment from Fraser Slip. Only three cores were collected from the slip in 2013 and one grab sample in 2007. Concentration of Pb peaked at approximately 588 to 590 ft (IGLD85) in Core HB13-47A but was present deeper at 587 to586 ft (IGLD85) in Core HB13-49A. The maximum concentration of 480 mg/kg was observed at the bottom of Core HB13-48B, at an elevation of 585 ft (IGLD85). Review of the nautical charts showed that approximately 4 ft of sediment may have deposited at Core HB13-47A, based on comparison of 2014 chart (Appendix B) to the 1943 chart (Table 1); this closely matches the core thickness of 3.5 ft recorded in the field. However, the sediment surface elevation that was based on the charts does not match the field record. There was about 10 ft of water overlying sediment when the core was taken in 2013 while the 2014 chart indicated potentially only 7 ft of water present. The discrepancy may stem from low display resolution on nautical charts because a detailed bathymetric map from USACE also showed about 10 ft deep in this places. Due to these uncertainties, no temporal information was evaluated.

PAH concentrations are relatively higher at locations HB13-47 and -48. The increasing trend of concentration in deeper sediment suggests historical input. Only one sediment sample was analyzed for organotin and the concentration was relatively low.

Table 1. Water depth and associated elevation for sediment cores from Fraser Slip

Chart Date (reference datum_ft)	**Sediment Cores**			
	HB13-47A		**HB13-48B and 49A**	
	WD[(1)] (ft)	**Elevation[(2)] (ft)**	**WD (ft)***	**Elevation[(2)] (ft)**
1943 (601.1)	11	590	13	588
1961 (601.6)	10	591	-	-
2013 (601.0)	7[10]	594[590]	11[12.4]	590[589]

(1) WD: Water Depth. WD for 2013 in [ ] is the field record. The rest is based on the nautical charts.

(2) Elevation in [ ] is the field record and the rest is based on the nautical charts.

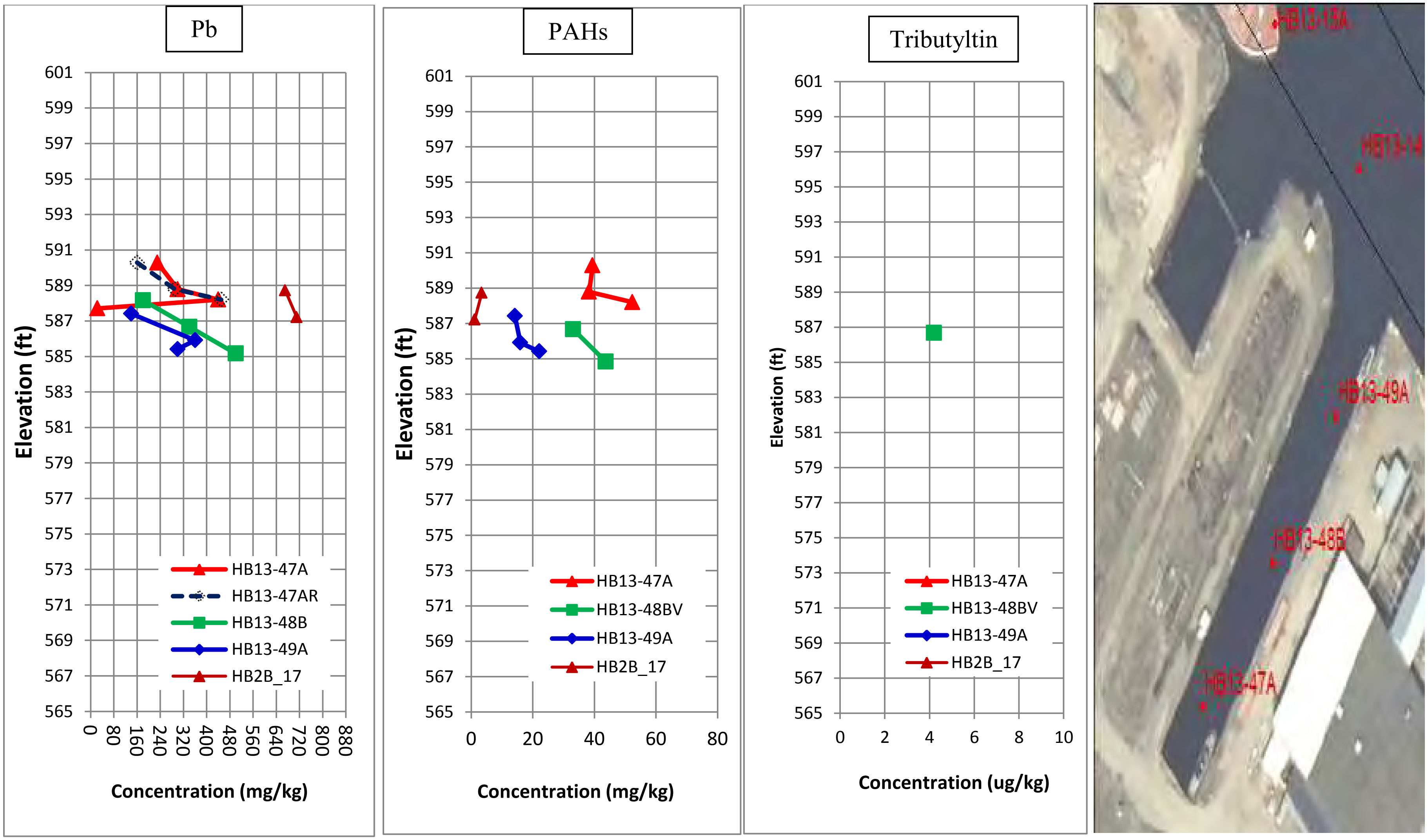


Fig. 13 Vertical profiles of Pb, PAHs, and tributyltin in sediment from Fraser Slip

3.4 Sediment Cores from the SE Corner (Management Unit 1)

Fig. 14 shows the distribution of Pb, PAHs, and tributyltin in sediment from the SE Corner (Unit 1) of the bay. There are two distinguished patterns observed as follows:

- Pb concentration is relatively low in the north side of the area, represented by Cores HB13-51, HB13-02, HB13-02R, HB10-2-26, HB10-2-41, HB10-2-42, and HB10-2-43, where surface sediment elevation ranged from approximately 593 ft to 600 ft (IGLD85). For the rest of the cores, higher concentration was detected at elevations ranging from 585 ft to 590 ft (IGLD85).
- The maximum concentration of 1,140 mg/kg of Pb in all samples collected from Howards Bay was detected in this location and in the surface at 589 to 588 ft (Core HB10-2-45). A similar maximum concentration of Pb was observed at the adjacent sediment Core (HB13-03) but the location of the maximum was present in a deeper segment, at about 584 ft.
- Higher surface sediment concentration of Pb was also present at Cores HB2B-18 and-_19, and HB10-44 and -45.
- The concentration of Pb at core HB 13-05 is included in Fig. 14 to illustrate how human action on waterways could affect the distribution of contaminants in sediment. Although the pattern of the vertical profile at this location is similar to that in the top 4 ft of the adjacent Core HB13-04, the surface sediment is located much deeper, approximately 25 ft below LWD due to dredging. The similarity of the distribution patterns between these two cores imply that the deeper area is influenced by shallow areas.
- Sediment located outside of the navigation channel could be transported to and deposited in the channel, potentially recontaminating the channel after navigational dredging if remediation at this location is not implemented.

To better understand potential sources for Management Unit 1, a relatively large management unit compared to other units, an attempt was made to estimate deposition rates for a few sediment cores. Table 2 summarizes the results based on a review of the nautical chart series. The Pb profile at Core HB13-01 showed a subsurface maximum at an elevation of 589 ft, indicating a useful core for analyses of sedimentation. Derived from temporal bathymetric changes, an average sedimentation rate of 0.1 ft/yr was estimated for the time period of 1950-1960 and 0.2 ft/yr for 1961 and 1970, respectively. Since 1970, sedimentation and erosion have potentially reached a dynamic equilibrium, with a slow rate of 0.03 ft/yr, assuming natural processes dominate sediment dynamics. A similar pattern was observed at Core HB10-2-44, but a faster deposition rate occurred in the 1970s. Subsequently, 2 ft of the deposited sediment appeared to have left the Core HB10-2-44 area between 2007 and 2013 according to the review of nautical charts. The significant change of sediment thickness between these time periods is suspected to be caused by sediment redistribution. This explanation may apply to Core HB10-45 as well. Therefore, source appointment based on vertical profiles needs to consider in-situ processes at some locations.

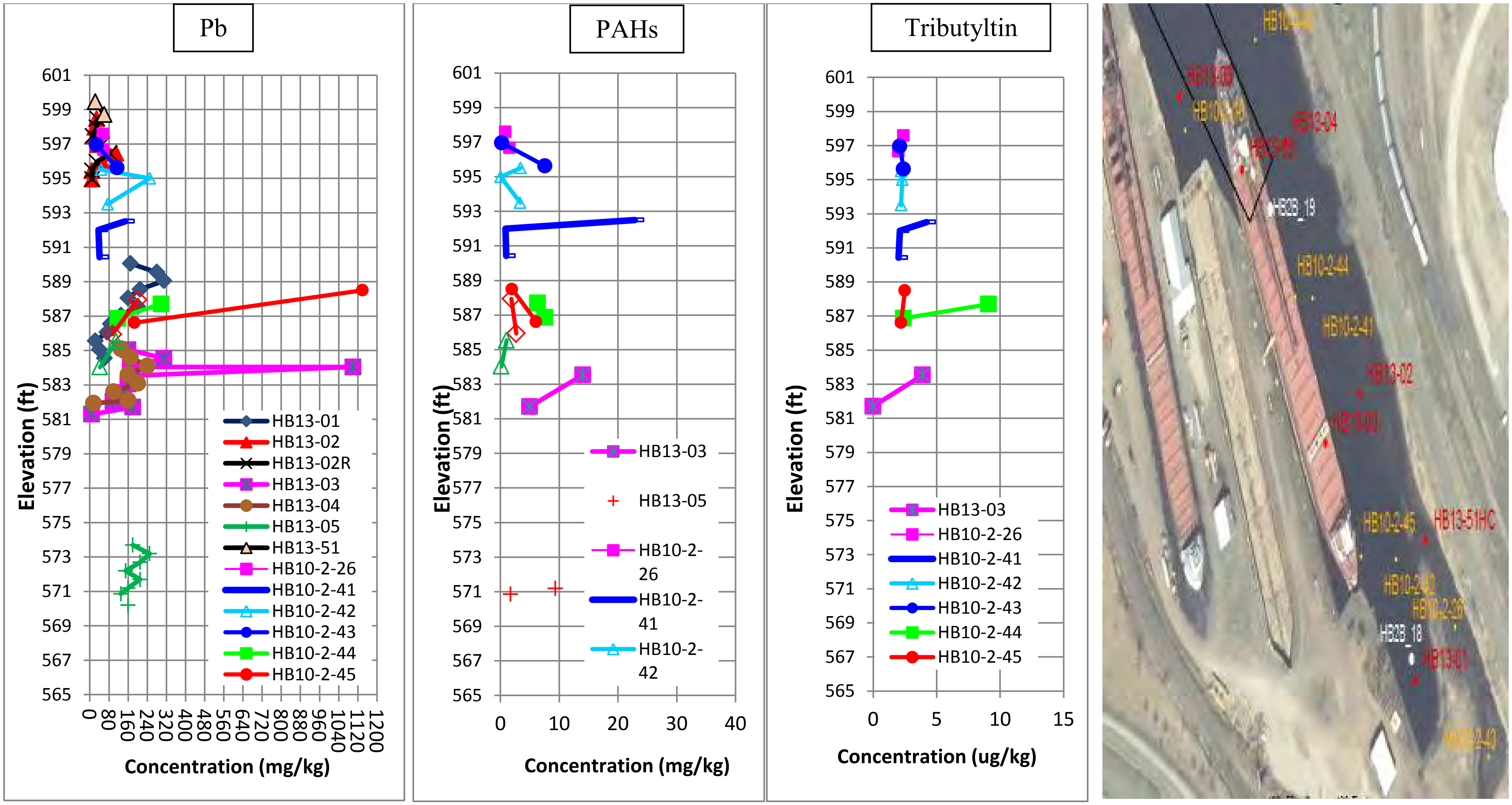


Fig. 14 Vertical profiles of Pb, PAHs, and tributyltin in sediment from the SE Corner

Table 2. Estimates of sedimentation rates at core locations in the SE Corner[(1)]

Chart Date (reference datum_ft)	**Sediment Cores**					
	HB13-01[(2)]		**HB10-2-44**		**HB10-2-45[(4)]**	
	WD (ft)	**Elevation (ft)**	**WD (ft)**	**Elevation (ft)**	**WD (ft)**	**Elevation (ft)**
1943 (601.1)	14	587	14	587	14	587
1950 (601.6)	14	587	14	587	14	587
1961 (601.6)	13	588	14	587	14	587
1964 (600.0)	11	589	14	587	14	587
1970 (600.0)	11	589	12	588	12	588
1973 (600.0)	11	589	12	588	12	588
1976 (600.0)	11	589	10	590	10	590
2007 (600.0)	10?	591?	10	590	10	590
2013 or 2010 (601.0)[(3)]	(10)	591	(13)	588	(12)	588
Estimated sedimentation Rate (ft/yr)						
1950-1961	0.1		-		-	
1961-1970	0.2		0.2		0.2	
1970-1976	-		0.4		0.4	
1976-2007 or 1976-2010 (2013)	0.03		-0.09		-0.06	

(1) The estimate was based on the selected nautical charts. Reference datum changed for different time period. WD: water depth.
(2) WD cannot be determined with reasonable certainty for year 2007.
(3) The water depth for 2013 and 2010 was based on sampling records, not the nautical chart.
(4) Changes of water depth on nautical charts may or may not apply to this core. But water depth recorded in field and core thickness suggests that it was reasonable to assign the core in this area.

Sediment core HB10-2-43 is interesting to note. This core was collected from the most southern end, where a small creek drains into the bay and a storm water outfall is located. The concentration of Pb is similar to the other two cores, HB10-2-26 and HB13-51, collected from downstream of the location. Except for a relatively higher level of Pb (114 mg/kg) in the subsurface, the concentration of Pb is low in the rest of the segments. PAH concentrations analyzed for selected samples were relatively low with the highest concentration of 23 mg/kg detected at Core HB13-41. The highest concentration of tributyltin among six cores analyzed was 9.1 ug/kg at the location of core HB10-2-44. Although the highest concentrations of Pb, PAHs, and tributyltin did not demonstrate coexisting pattern as observed at Cumming Ave. Slip, in general they are located in the same vicinity at the south side of the SE Corner.

As a summary, in general the majority of contaminated sediment in the SE corner was deposited between the 1950s and 1970s, based on the review of Pb profiles combined with the information obtained from nautical charts. The faster deposition rate between the 1950s and 1970s may reflect development in the time period, such as the construction of the Interstate HWY Bridge I-535.

3.5 Sediment cores from Area A8

Fig. 15 shows that the Pb profiles in sediment cores from Area A8. As summarized in Table 3, a total of 11 sediment cores were collected from this area since 2007.

Table 3. Sediment cores from Area A8

Core ID	Surface Elevation (ft)	Bottom Elevation (ft)	Maximum Concentration
HB2A_P6	594.2	-	26
HB2A_P7	584.5	-	33
HB2A_P8	580.3	-	110
HB10-1-03	577.8	570.8	60
HB10-1-04	598.5	594.3	55
HB10-1-07	596.5	591.1	53
HB10-1-10	573.9	-	39
HB13-29	573.7	570.0	110
HB13-30	577.1	570.6	78
HB13-31	573.8	571.1	54
HB13-32	573.4	570.7	68

Overall, the Pb concentration in these cores is relatively low with an average of 42 mg/kg. The maximum Pb concentration is 110 mg/kg at Cores HB13-29 and HB2A_P8. Historically, the area was dredged to 29-30 ft (570-571 ft IGLD85) in 1963, which is the deepest on record and about two years after the bridge was built. This 1963 elevation mark matches the bottom of the core length at HB13-29, - 30, -31,and -32. Assuming the bottom of Core HB13-30 ft (at an elevation of about 571 ft) was the result of dredging in 1963, the average sedimentation rate was then estimated to be 0.1ft/yr. This was derived from the ratio of sediment thickness and the time period between the years 1963 and 2013. Based on this rate, the maximum Pb concentration of 78 mg/kg may have been deposited at the location in the late 1970s to early 1980s. If the similar sedimentation rate is applied to Core HB13-29, the bottom of the sediment with the highest concentration might have been deposited earlier than the 1970s.

PAH profiles in samples analyzed showed a relatively higher concentration in the surface at Core HB10-07. Relatively higher tributyltin detected in sediment from this area may be because of the close proximity to Hughitt Ave. Slip, where the highest concentration of tributyltin was detected.

Multiple sources could have contributed Pb to Area A8. In addition to the direct runoff from the HWY I-535 Bridge, sediment from other portions of the bay is expected to accumulate in this area.

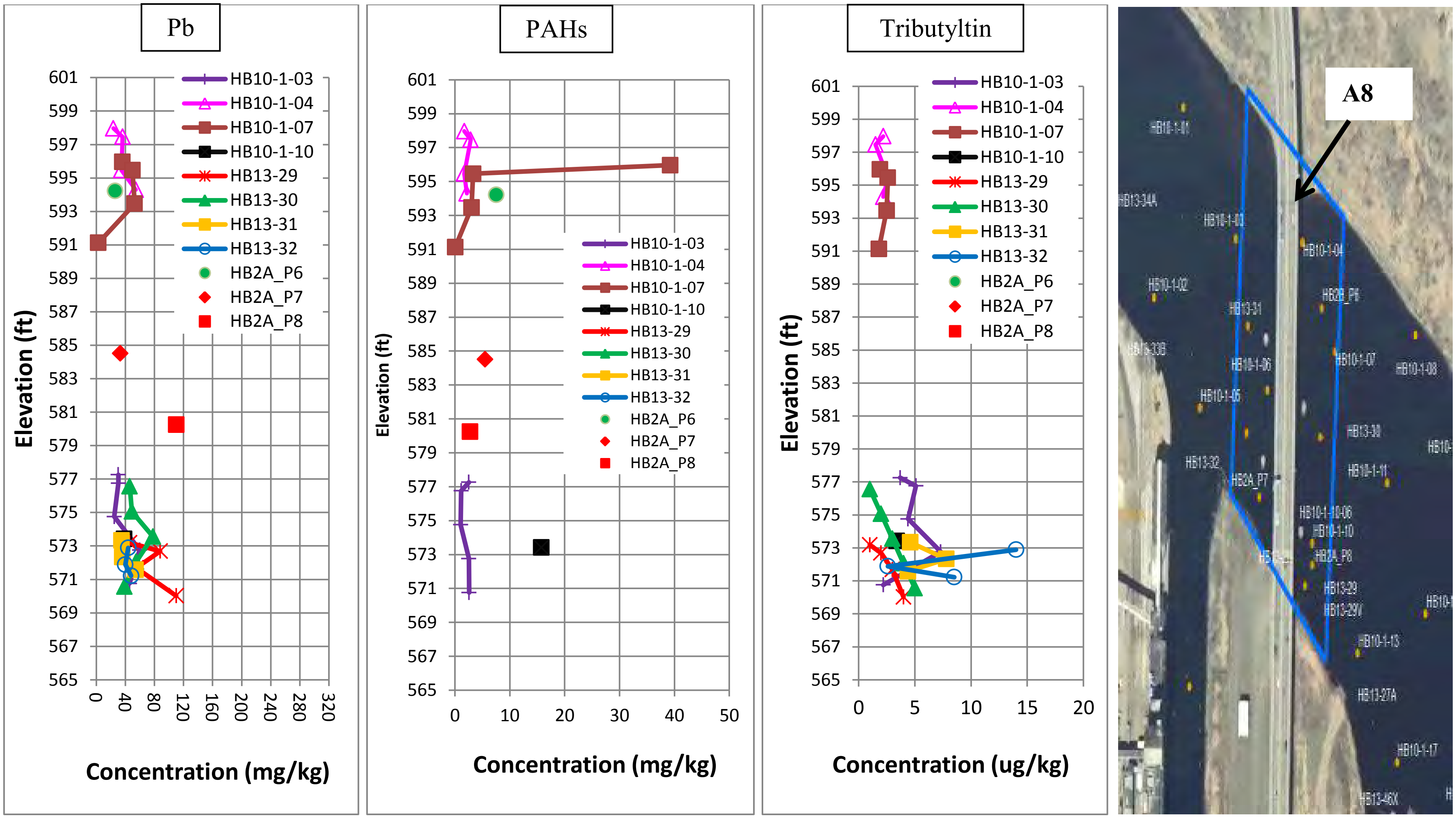


Fig. 15 Vertical profiles of Pb, PAHs, and tributyltin in sediment from Area A8 (see the context for the delineation of the area)

4. QUANTITATIVE ANALYSES OF SOURCES

A quantitative analysis was conducted for the identified sources to determine the contribution of the sources to sediment based on a mass balance approach, which assumed that contaminants present in the sediment at selected locations were deposited during a specific time period, and that after deposition redistribution of sediment out of these selected areas was negligible.

It is assumed that contaminants present in sediment ($\mathbf{M_{sed}}$) in the selected locations were contributed by background storm water runoff ($\mathbf{L_b}$), air deposition ($\mathbf{L_{air}}$), and incidental input ($\mathbf{L_{ii}}$) as expressed in equation (1) and illustrated in Fig. 16:

$$\mathbf{M_{sed} = L_b + L_{air} + L_{ii}} \qquad (1)$$

where $\mathbf{M_{sed}}$ is the mass of a contaminant in sediment; $\mathbf{L_b}$ is the mass loading from the background storm water runoff, $\mathbf{L_{air}}$ is the mass contributed from direct air deposition, and $\mathbf{L_{ii}}$ is the incidental input.

For this study, $\mathbf{M_{sed}}$, $\mathbf{L_b}$, and $\mathbf{L_{air}}$ can be estimated with the available information, but the incidental input ($\mathbf{L_{ii}}$) cannot be estimated directly due to its unknown nature. $\mathbf{L_{ii}}$ was assessed by subtracting the sum of the loading from background storm water runoff and direct atmospheric deposition from mass in sediment. The results from the mass balance analyses determined the relative significance of $\mathbf{L_b}$, $\mathbf{L_{air}}$, and $\mathbf{L_{ii}}$ contributions to contaminants present in sediment. Furthermore, assuming $\mathbf{L_{ii}}$ will be eliminated through best management practices, concentration of Pb in sediment was predicted after remediation.

A complete analysis was conducted for Pb at three locations: Cummings Ave. Slip, Fraser Slip, and the SE Corner. The results for Hughitt Ave. Slip and Area A8 were tentative due to complication of sediment dynamics in these two locations. No storm water outfall is located in Hughitt Ave. Slip. Both areas are subject to more frequent dredging and Area A8 may receive sediment transported from other portions of the bay due to a focusing factor. In-situ sediment transport was not part of the scope of the study.

PAHs and organotin were not included in the mass balance analyses due to insufficient information about historical source and sediment data. Post remediation PAHs in sediment from MS4 discharges were assessed based on the City of Superior storm water samples collected from the outfalls in Cummings Ave. and Fraser Slips, and the SE Corner in 2013 and 2014.

4.1 Mass Loading of Pb from Background Storm Water Runoff

4.1.1 General Information

Since the 1970s, federal and state agencies and researchers have recognized that contaminants present in runoff can adversely impact water quality in streams and lakes [USEPA, 1983; Cole *et. al*, 1984; Mustard *et. al*, 1987; USEPA,1972; Pitt, 1985; and Davis *et. al*, 2001]. In concert with a national effort, Wisconsin DNR and the US Geological Survey (USGS) have conducted

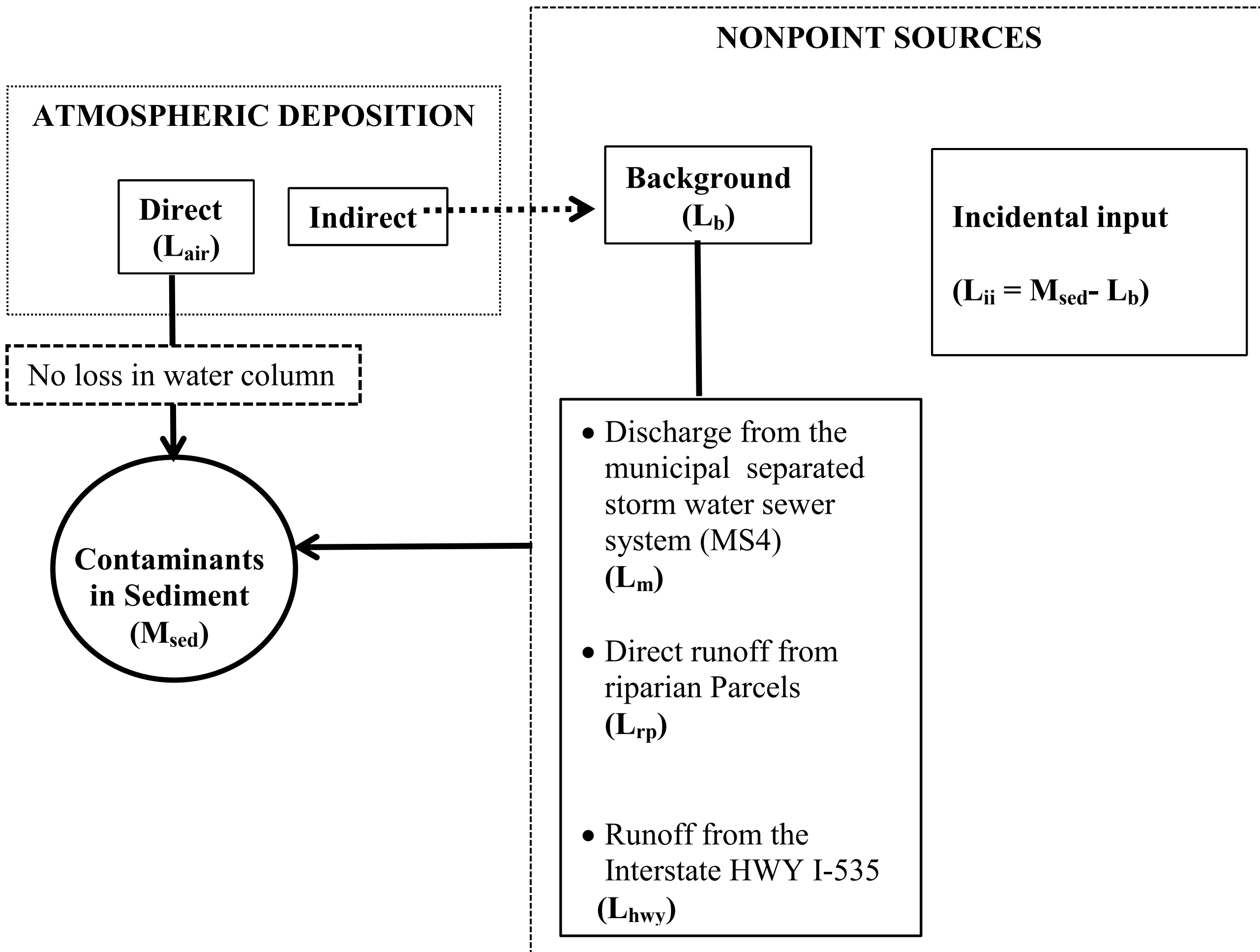


Fig. 16 Conceptual mass balance approach for quantitative analyses of sources

various studies of contaminants in runoff since the 1970s [WDNR 1983; Bannerman, *et al.*1996; WDNR 1992; Walker, 1993; USGS and WDNR 1995].

These studies have shown that contaminants are detected frequently in storm water runoff. However, the amount of contaminants in storm water that eventually reaches an aquatic system or Howards Bay is governed by multiple factors, such as local climate, precipitation intensity and duration, runoff water collection system design, and topography, as well as storm water management programs.

The City of Superior received an annual average rainfall of approximately 29 inches and snowfall of 50 inches between1947 and 2013 (NOAA, 2014). On average, the city receives the most rainfall between June and September and the most snow in December and January as shown in Fig. 17. In general, snow starts melting in March, when monthly high temperatures rise over 32^{o}F (Fig. 17); however, sometimes snowfall occurs in warmer months (Fig. 18).

Pb detected in storm water runoff exists in two phases, dissolved and particulate. Because of its high affiliation with particles, the concentration of Pb in runoff is strongly related to the total suspended solids (TSS). According to Morquecho et al. (2005), nationwide, about 79% of total Pb was associated with particulates. Studies also reported higher proportion, up to 99%, of total Pb in the particulate fraction and highly correlated with TSS in storm water runoff [Hewitt and Rashed, 1992, and Thomson e*t al*., 1997]. Furthermore, other studies show that a large fraction of particulate Pb was associated with fine clay size particles smaller than 4 micrometers (*u*m) [USEPA, 1972]. Table 4 shows that the fraction of clay size particles in runoff is small at only 0.5 percent. The majority of the particles are in the sand size range, representing approximately on average over 86% of the suspended solids in runoff. Larger size particles settle out earlier along the delivery pathway; therefore, the smaller sized particles (i.e. silt and clay) govern the fate and transport of Pb from source areas to aquatic systems.

Table 4. Particle distribution in urban storm water runoff *

Particle size range (*u* m)	MILWAUKEE	BUCYRUS	BALTIMORE	ATLANTA	TULSA	Avearge
Sand %, 43-4,800 um	92.1	74.1	82.1	91.9	92.3	86.5
Silt %, 4-43um,	7.4	25.9	17.1	7.8	7.6	13.2
Clay %, < 4 um	0.5	-	0.9	0.3	0.1	0.5

* Reference: USEPA, 1972

The concentration of Pb in runoff is also source dependent. Often, the concentrations are higher in runoff originating from industrial and commercial areas compared to residential areas. Runoff from roofs contains greater levels of Pb than runoff from vegetated areas such as lawns. Areas adjacent to highways may generate a higher content of Pb [Pitt et. al, 2004]. However, the loads from individual source areas can be changed through the implementation of water quality best management practices.

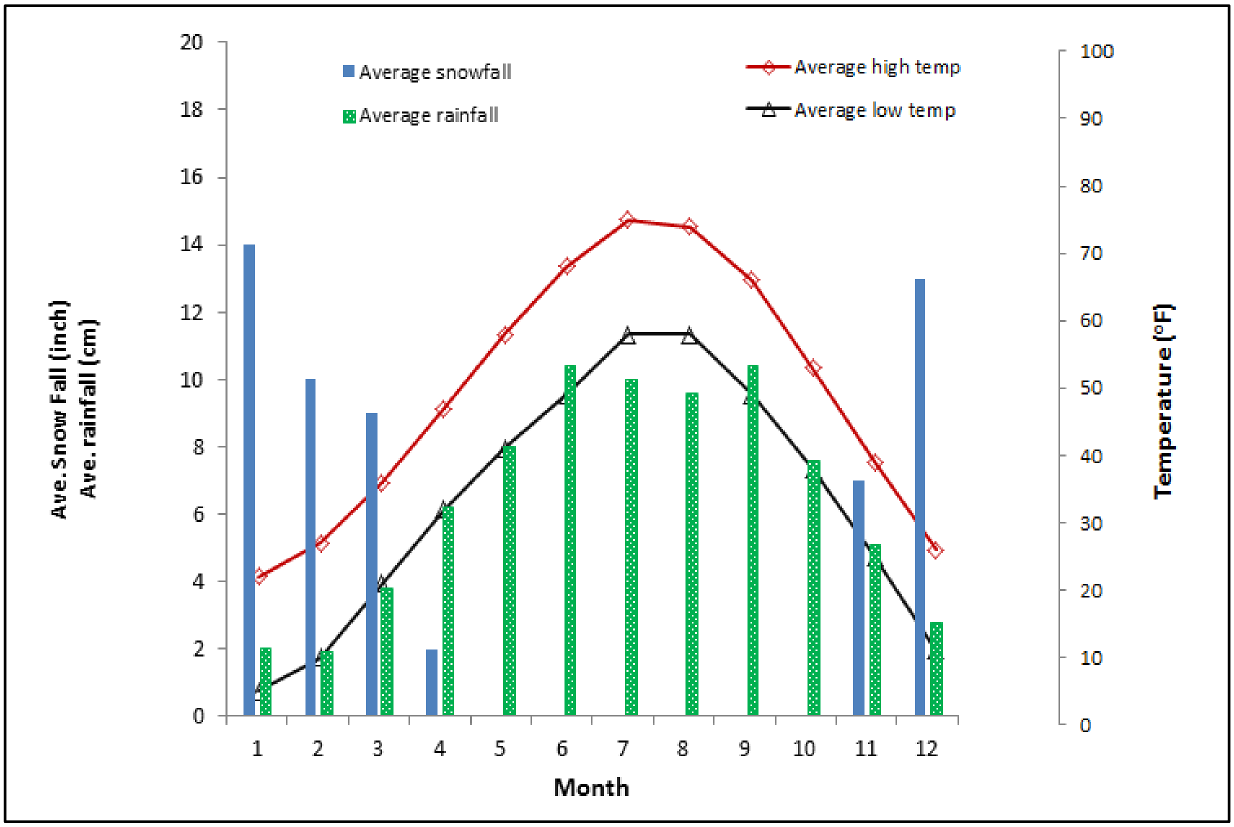


Fig. 17 Monthly snowfall and air temperature between 1947 and 2013 (NOAA, 2014 and National Climate Data Center- www.usclimatedata.com)

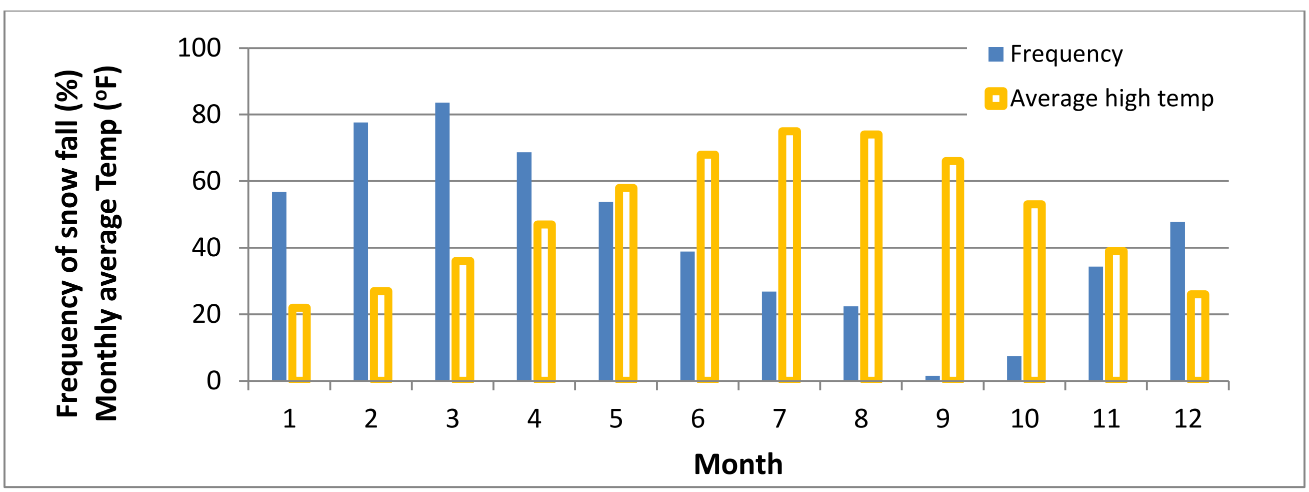


Fig. 18 Frequency of monthly snowfall between 1947 and 2013 (snowfall data- NOAA, temp - www.usclimatedata.com)

4.1.2 Monitoring Data

4.1.2.1 Concentrations of TSS and Pb in the Background Storm Water Runoff

Available data of TSS and Pb in runoff were compiled to evaluate the water quality of runoff from urban areas and used for assessing mass loading of lead to Howards Bay from background storm water runoff. A three-tiered approach was taken to compile relevant data. The first tier was to find site-specific data, where available. The second tier was to find data collected in Wisconsin if site specific data were not available. Finally, if both site specific or statewide data were not available, then nationwide information was reviewed and used when necessary.

In compiling runoff concentration data, it was recognized that results were complicated by the sample collection methods used. The results can also be affect by when the samples were collected during a storm and in which season of a year [Paul, 2001]. Samples can be collected instantaneously as discrete “grab samples”, as “composite samples” over an entire rainfall event or as composites from only a portion of an event (as in the case of “first flush” samples), or throughout an event until the capacity of a sampling device was full. Researchers often used event mean concentration (EMC) as a parameter to evaluate data over the duration of a storm water runoff event. Different sampling methods can make the comparison of data difficult. For this assessment, the data were used as they were originally collected, and the majority of data compiled were instantaneous grab sample results.

WDNR’s Surface Water Integrated Monitoring System (SWIMS) contains a large database of water quality data (i.e., physical, chemical, and biological). The department’s files also include data from special studies. A review of these primary WDNR data sources for the time period between the 1970s and 2013 found no results from within the project area. The most geologically relevant data were a few event samples collected from a station located in the City of Superior at the intersection of Tower Avenue and 32 Street, a several miles from the project area as shown in Fig. 19. The runoff this station represents does not discharge to Howards Bay but the data were integrated into the statewide database for the study.

Site specific data collected in 2013 and 2014 were obtained from the City of Superior. The city collected samples from the MS4 outfalls discharging to Howards Bay. Four composite samples, taken to the capacity of the sampler during each event, were collected. Therefore, this first tier data search effort concluded that evaluation of historical storm water runoff sources, i.e., prior to 2013, would be based on non-site specific data.

As a result of the second tier of data search, over 800 TSS and 300 Pb discrete storm water runoff data points were retrieved from SWIMS, respectively, covering the time period of 1975 through 2012. All of the selected data were collected from urban sites as part of the effort through national and state nonpoint source programs. Almost all of the sampling stations were located in Milwaukee and Madison, Wisconsin except for one station in the City of Superior, as discussed earlier. These stations are illustrated in Fig. 19. Data collected from these stations represent urban settings with mixed land use types ranging from residential to commercial and industrial types.

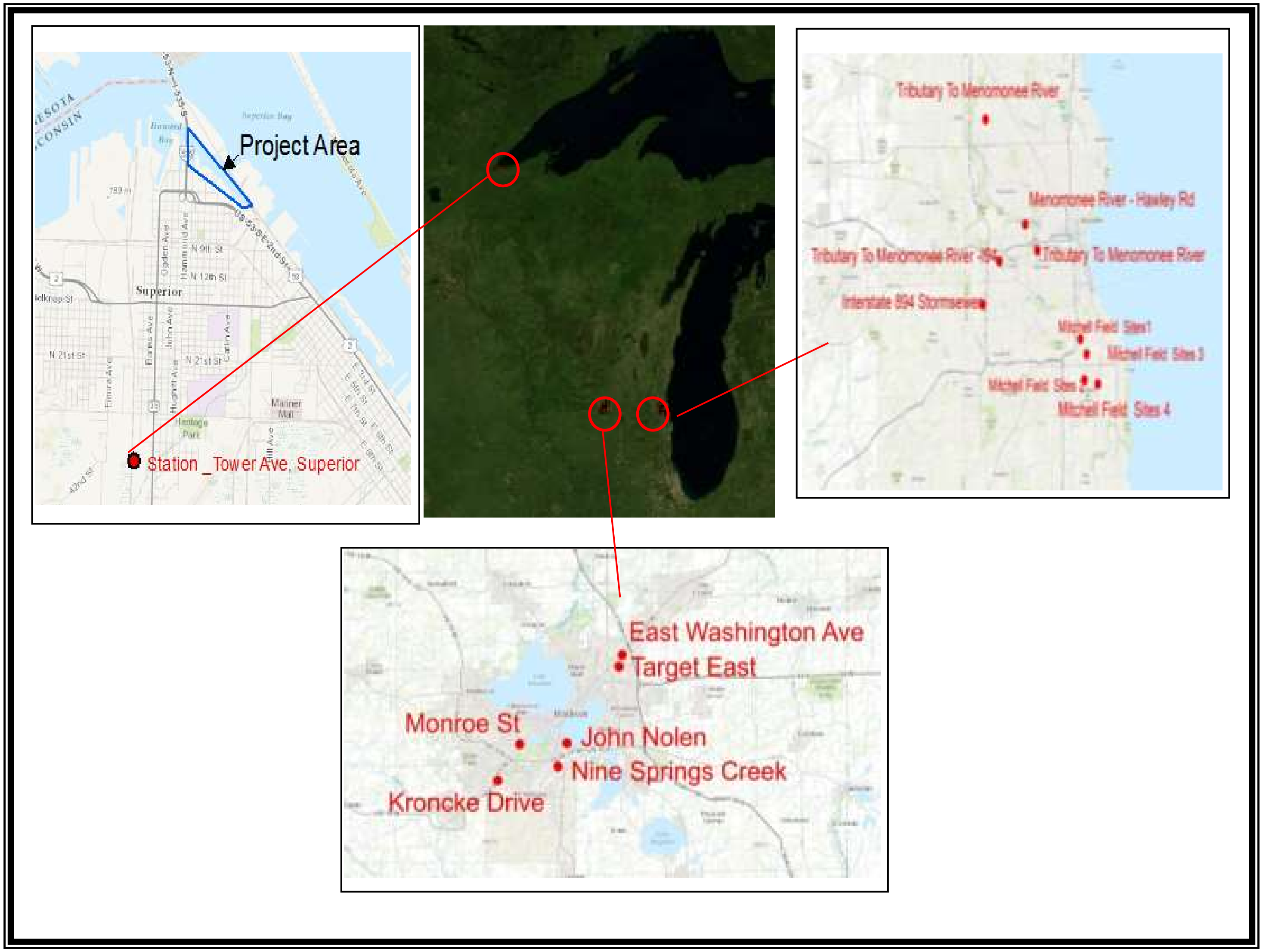


Fig. 19 Statewide urban runoff sampling locations

With the understanding of the time line of urban development and implementation of environmental protection programs, the retrieved data were further divided into different time periods of 1975-1977, 1990-1995, and 2000-2012, respectively. Unfortunately no data prior to 1975 or for the time between 1978 and 1990 was found on SWIMS. The data gap was then filled with information published as reports from other studies nationwide, when applicable. Table 5 summarizes statistics of the datasets for these three different time periods. Also included in Table 5 are the data collected by the City of Superior in 2013 and 2014.

On average, the concentration of total Pb (T_Pb) decreased from 58 micrograms per liter (ug/l) to 5 ug/l between 1975-1977 and 2000-2012. For the same time periods, the average TSS concentration also decreased from 230 to 88 milligrams per liter (mg/l). The average particulate Pb (P_Pb) concentration decreased from 205 to 61 mg/kg between 1990-1995 and 2000-2012. The most recent data collected from the MS4 outfalls in Howards Bay in 2013-2014 (Tier 1) were comparable to the data collected from statewide urban sites between 2000 and 2012, although the P_Pb was higher. On the other hand, the 2013-2014 P_Pb were similar to the 1990-1995 dataset.

Data collected since the 1990s by the USGS and WDNR (SWIMS database) show that out of 270 samples analyzed, Dis_Pb was detected in 50% of the samples and was less than 1.5 ug/l in 90% of the samples, as shown in Fig. 20. For mass loading analyses, the T_Pb was assumed to be all associated with particles and deposited to sediment after entering the water body from various sources.

The non-site-specific data collected in earlier years may well represent TSS and Pb concentrations, but some points are worth noting. With a larger population in Milwaukee and Madison compared to that in the City of Superior, applying statewide data for the follow up evaluation may be conservative. For instance, data collected from the Mitchell Airport field in Milwaukee may not represent the typical environment in the Howards Bay watershed; however, with the consideration of indirect air deposition, this data was included to represent the impact from the nearby airport in Duluth, Minnesota.

4.1.2.2 Concentration of Pb in Storm Water Runoff from the Interstate HWY I-535

Runoff generated from interstate highways is unique, i.e., related to the road and vehicles. Substantial studies have been conducted nationwide starting in the early 1970s [Gupta *et al.*, 1981; Lord, 1987; USDOT, 1990; and Malina et al. 2006]. Data were obtained from different sources as listed below and summarized in Table 6:

- Discrete sample results reported were from an I-894 station during the time period of 1999-2000. This dataset was abstracted from the WDNR SWIMS database.
- Data reported in event mean concentration (EMC) by US Department of Transportation [USDOT, 1990a and 1990b] for the Milwaukee I-794 site between 1976 and 1977.
- Summary results from 1978 and 1982 by the National Urban Runoff Program [USEPA,1983]. No average concentrations can be evaluated only the median and the ranges were reported for this data set.

Table 5. Summary Statistics of TSS and Pb concentrations (1975-2014)[1]

Parameter	Time Period											
	1975-1977[2]			1990-1995[2]			2000-2012[2]			2013-2014[3]		
	TSS (mg/l)	**T_Pb (ug/l)**	**P_Pb[5] [6] (mg/kg)**	**TSS (mg/l)**	**T_Pb (ug/l)**	**P_Pb[5] (mg/kg)**	**TSS (mg/l)**	**T_Pb (ug/l)**	**P_Pb[5] (mg/kg)**	**TSS (mg/l)**	**T_Pb (ug/l)**	**P_Pb (mg/kg)**
Sample number (n) [4]	725	199	NA	52	48	48	74	89	74	12	12	12
Average	230	58	NA	160	29	205	88	5	61	67	7	224
Median	104	14	NA	115	22	187	59	4	60	20	4	203
Minimum	1	0.01	NA	18	4	57	5	ND	ND	2	1	43
Maximum	3,588	880	NA	524	79	453	568	151	235	318	32	450

(1) Concentrations reported with a string of "ND" were treated as zeroes. Data with other qualifiers, such as "J", were excluded for analyses. Data collected from interstate highways were excluded for this statistical analysis.

(2) Data source: Wisconsin DNR Surface Water Integrated Monitoring System (SWIMS) and other project reports. P_Pb was not calculated for the data set of 1975- 1977 and some of the 1990 and 1995 sets.

(3) Data source: City of Superior - Outfall composite samples collected from the outfalls located in Howards Bay

(4) Listed units do not apply to the sample number.

(5) Not reported directly from the SWIMS database, value was calculated by using T_ Pb and TSS concentration data collected simultaneously at each sampling station.

(6) No sampling time was reported for T_Pb, and therefore, no particulate phase Pb concentration could be calculated for a large number of samples so it is listed as NA (not analyzed). However, to have a screening level understanding, median values of TSS and Pb would result in 140 mg/kg for P_Pb.

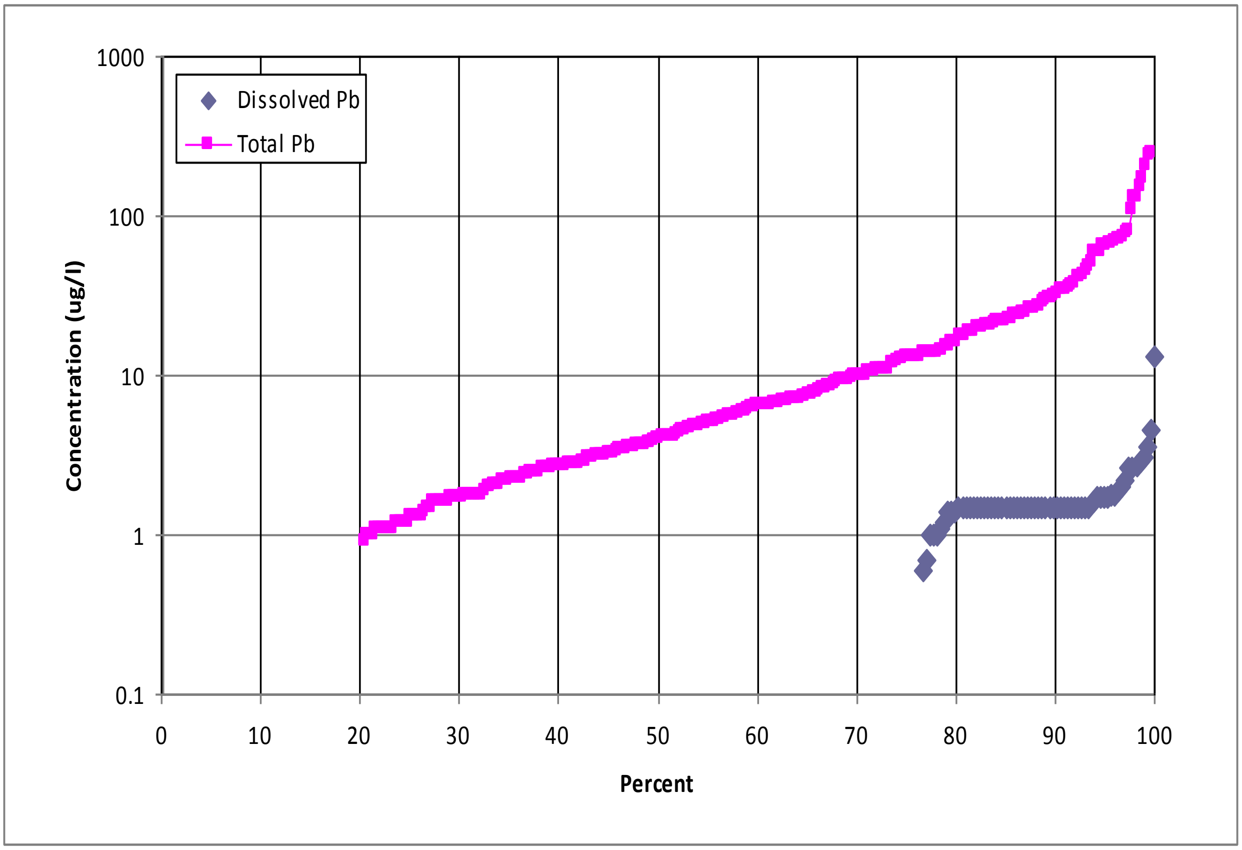


Fig. 20 Cumulative distribution of total and dissolved Pb in runoff samples (data source: WDNR SWIMS)

Table 6. TSS and Pb in runoff from Interstate Highways

Parameter	Highway Storm water Runoff								
	1976-1977 HYW I-794 (EMC,USDOT)(1)			1979 -1982(2)			1999-2000 HYW894(3)		
	TSS(4) (mg/l)	Pb (ug/l)	P_Pb (mg/kg)	TPM (mg/l)	Pb (ug/l)	P_Pb (mg/kg)	TSS (mg/l)	Pb (ug/l)	P_Pb (mg/kg)
Sample number (n)(5)	25	17	NA	NA	NA	NA	33	33	33
Average	172	1590	NA	NA	NA	NA	286	47	216
Median	140	1460	NA	NA	57	NA	98	26	214
Minimum	26	800	NA	6	ND	NA	ND	5	ND
Maximum	475	3100	NA	2160	6,300	NA	4,232	250	823

(1) National Urban Runoff Program (EPA,1983)

(2) Data source: (FHA, 1990a and 1990b)

(3) Data source: Wisconsin DNR Surface Water Integrated Monitoring System (SWIMS). All data were used without consideration of seasonal variation.)

(4) An extremely high TSS value of 7,270 mg/l was reported, but Pb was either not analyzed or not reported so it was not included in this study and can be assumed to be an anomalous.

(5) Listed units do not apply to the sample number.

EMC event mean concentration

NA not available

ND not detected

TPM total particular matter

As shown in Table 6, the average T_Pb concentration decreased from 1,590 ug/l to 47 ug/l for the two time periods of 1976-1977 and 1999-2000, regardless of whether the data was discrete or an event mean concentration. The maximum T_Pb concentrations of 3,100 ug/l and 6,300 ug/l, reported in the 1970s and early 1980s by USDOT [1990b], may be attributed to many factors, one being Pb was an additive in gasoline in the past. Due to higher median concentration (1,460 ug/l) observed in 1976-1977 when compared to that in 1979-1982 and 1999-2000, it can be concluded that a high concentration of Pb was detected more frequently in 1976-1977. An average P_Pb concentration of 216 mg/kg was estimated for the runoff data from Interstate HYW I-894 for the time period of 1999 to 2000.

The above comparative analyses may carry high uncertainties because samples were collected from different highways with different objectives. However, due to the fact that the samples were collected from the same city, comparison for a general temporal trend is considered a valid approach. Note that extrapolation of the data collected from these highways to Interstate HWY I-535 may be biased high because traffic flow on HWY I-535 is much lighter than that on either HWY I-894 or HWY I-794.

4.1.2.3 Seasonal Variation of Concentrations in Runoff

Snowmelt can generate a high volume of water and transport contaminants that have accumulated in the snow to a water body. The majority of runoff data retrieved was collected during non-winter seasons. To provide a screening level evaluation on whether runoff water quality differs significantly in rainfall compared to that in snowmelt, the data presented in Table 5 were separated into winter and non-winter seasons. A calendar year was divided as November to March for the winter season and April to October for non-winter seasons, respectively. Table 7 summarizes the seasonal variation of TSS and Pb for runoff from both highways and non-highway sources.

As shown in Table 7, the runoff in non-highway samples did not exhibit significant difference between the two seasons for TSS and Pb. Runoff from highways showed a trend. During the winter season, runoff from highways contained less total suspended solids than in non-winter seasons (on average 197 mg/l versus 330 mg/l, respectively), but a relatively higher T_Pb concentration (on average 31 ug/l versus 65 ug/l, respectively). The same trend for T_Pb applies to P_Pb for highway runoff data. The variation is important in loading analyses; therefore, the follow up quantitative analyses were carried out for two seasons using different concentration values for highway runoff.

4.1.3 Methods and Parameters for Mass Loading Estimation

Fig. 21 illustrates the methods for estimating mass loading of Pb from background storm water runoff for a time period of 1981 through 1985. A number of methods have been developed to estimate and predict pollutant loading from storm water runoff [Huber and Dickinson 1988;

Table 7. Seasonal variation of TSS and Pb concentrations in runoff

	Season											
	Non-winter						Winter					
	HYW 894 (1990-2000)			All other sites			HYW 894 (1990-2000)			All other sites		
Parameter	**TSS (mg/l)**	**Pb (ug/l)**	**P_Pb (mg/kg)**	**TSS (mg/l)**	**Pb (ug/l)**	**P_Pb (mg/kg)**	**TSS (mg/l)**	**Pb (ug/l)**	**P_Pb (mg/kg)**	**TSS (mg/l)**	**Pb (ug/l)**	**P_Pb (mg/kg)**
Sample number (n)	22	22	22	85	99	85	11	11	11	37	42	37
Average	330	31	182	116	14	110	197	65	286	140	17	133
Median	95	21	168	80	7	83	104	38	327	80	10	82
Minimum	5	ND	ND	5	10	0	5	0	0	17	1	41
Maximum	4,232	210	823	568	151	453	756	250	467	456	72	333

* 1976-77 highway data: event mean concentration. All other data: discrete data points. There are no winter data for HWY I-794.

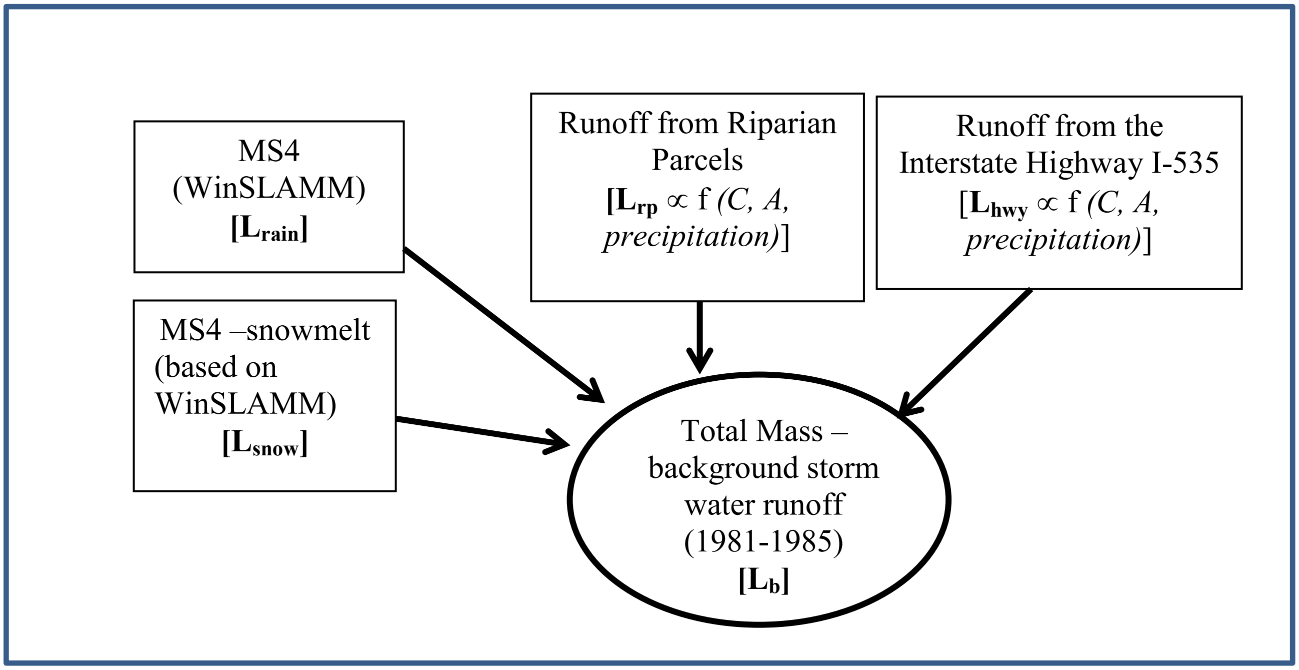


Fig. 21 Methods of mass loading analyses for background storm water runoff
(L_{rain} – loading generated by rain, L_{snow} – loading generated by snow, L_{rp} and L_{hwy} – loading from riparian parcels and highway I-535 which are a function of C- concentration and A – surface area, and L_b – the total mass loading from background runoff)

Pitt and Voorhees, 2002; Francey et al., 2011; and Bannerman *et al.*, 1996]. The Source Loading and Management Model for Windows (WinSLAMM) version 10.0 was used to simulate the mass loading of Pb carried by rain and discharged from the MS4 (L_{rain}). Mass loading from snowmelt (L_{snow}) was calculated as proportional to the amount of mass generated by rainfall storm water runoff that was predicted by WinSLAMM. The mass amount in the storm water runoff from riparian parcels was estimated as a function of the concentration of Pb in runoff, the size of the area, and the volume of precipitation (L_{rp}). The precipitation volume was set the same as applied to the WinSLAMM model. This method was also applied to estimate mass loading from the Interstate HWY I-535 (L_{hwy}). The sum of total mass from the pathways represented the total loading from background storm water runoff (L_b). The time domain of 1981-1985 was pre-determined by the WinSLAMM model input files established for the state of Wisconsin (USGS, 2015)

4.1.3.1 WinSLAMM modeling for Pb in runoff from MS4

The WinSLAMM model is one of the tools developed and widely used for assessing loading of contaminants from urban storm water runoff since the 1970s [Pitt and Voorhees, 2002]. The model is an accepted tool for estimating loading as part of the WDNR storm water discharge permitting program, ch. NR 216, Wisconsin Administrative Code, and to determine compliance with the performance standards in ch. NR 151, Wis. Adm. Code. Wisconsin administrative code ch. NR 151 and has been applied for different projects. Important parameters for the WinSLAMM model simulation include weather condition, drainage area of the storm water sewershed, land use types, and the concentration of contaminants from each source area associated with a land use type. A set of input data files has been developed for the time period of 1981-1989 by the USGS and Wisconsin DNR based on analyses of records collected between the 1970s and 1990s. The representative urban area closest to the City of Superior in the input set files is located in Duluth, MN (http://wi.water.usgs.gov/slamm/ and USGS, 2015).

Record of rainfall and snowfall for the City of Superior

Under ch. NR 151, permitted municipalities in developed urban areas such as the City of Superior need to use 5-year rainfall data to simulate the output from MS4 discharges and for evaluating the effectiveness of their storm water management plan implementation. The model simulation time period of 1981-1985 was selected by the USGS and Wisconsin DNR based on the historical records from 1949 to 1992 from the National Weather Service. The hydrology of this time period represents the average annual rainfall and average five-year rainfall. Fig. 22 shows that the precipitation received during 1981-1985 in the City of Superior is within the average level in a long term record although the model input file was based on records from Duluth, MN.

For this study, WinSLAMM simulated runoff for a total of 439 rainfall events between 1981 and 1985, a total rainfall depth of 153 inches and volume of $1.23x10^7$cubic feet (cft). This rainfall amount is comparable to the actual record of 168 inches for the City of Superior reported by NOAA (2014).

Land use types for the WinSLAMM model

Both Douglas County and the City of Superior have developed GIS coverage for land use types and the MS4. When the WinSLAMM model simulation was constructed, the land use types and associated areas were constructed based on the geospatial datasets obtained from the county's website (http://www.ci.superior.wi.us/index.aspx?nid=474). Land use types within the watershed were classified into four categories: commercial, industrial, residential, and park & open space. Within each land use type, the storm water source areas were further defined as listed in Table 8. The commercial and industrial land use types were combined as industrial for running the model. As a reference, Table 9 summarizes the concentrations of TSS and Pb in the model input file.

After the model simulation was completed, the City of Superior provided an updated database for land use types. Some discrepancies were observed when the two sets of GIS database were compared. While the majority of the land use was comparable for both the Fraser Slip and SE Corner outfall drainage areas, some discrepancies exist. The major difference was the areas classified as industrial vs. commercial land use for Cummings Ave. Slip and the SE Corner, as shown in Fig. 23. To evaluate the uncertainties that could be attributed to the land use types, a sensitivity test was run by using two datasets; the results of the sensitivity simulation will be discussed below.

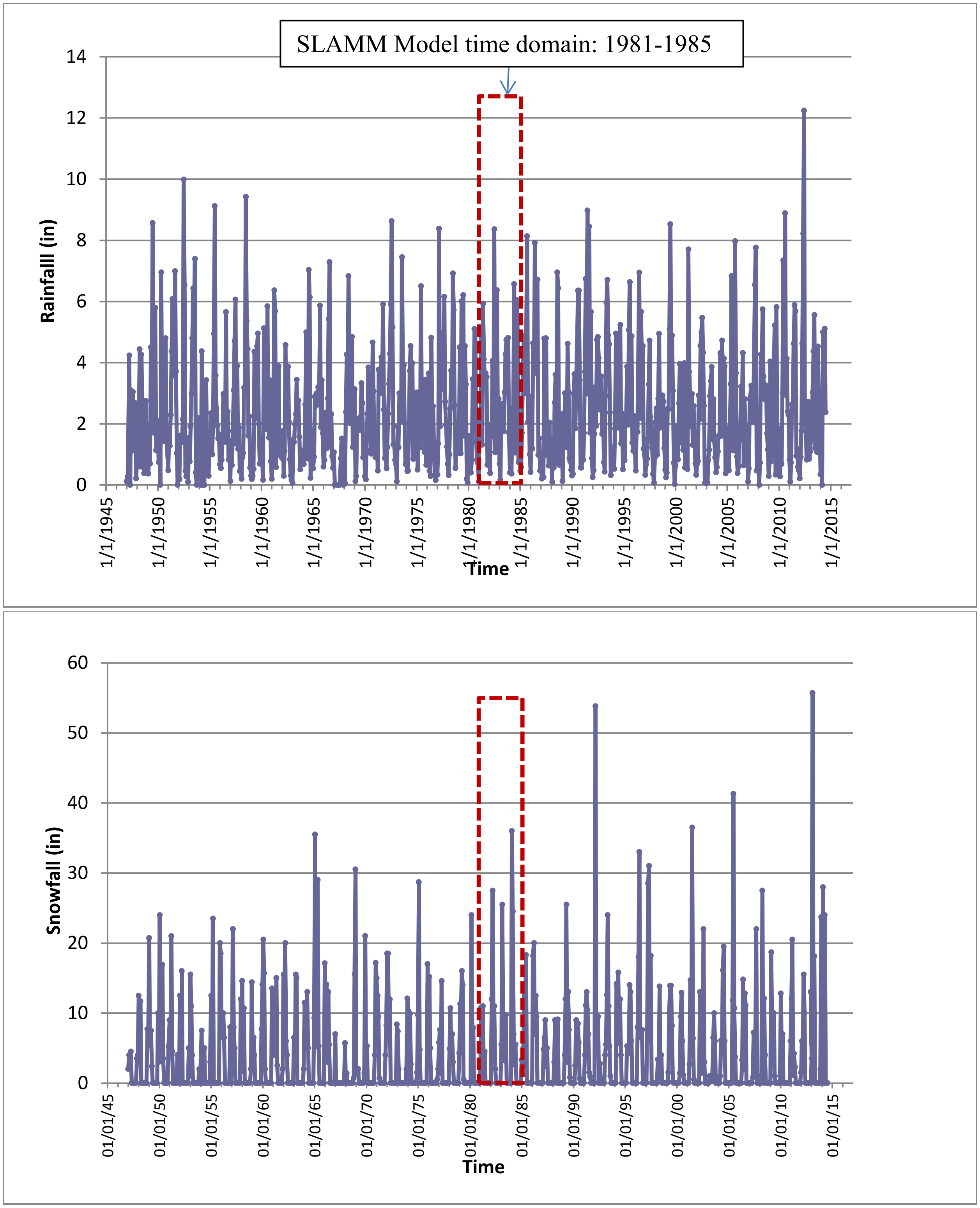


Fig. 22 Records of monthly average rainfall and snowfall for the City of Superior (NOAA, 2014)

Table 8. Distribution of source areas for land use types configured in the WinSLAMM model *

Land Use Type	Roofs	Paved Parking/ Storage	Paved Driveways and Sideways	Streets	Landscaped areas	Other pervious areas	Playground	Isolated areas	Other Imp. Areas
Medium Industrial	**23.1**	**48.7**	**3.7**	**7.5**	**12.2**	**4.8**	**NA**	**NA**	**NA**
Strip Commercial	**23.4**	**42.3**	**6.3**	**20.1**	**6.0**	**1.0**			
Medium Density Residential with Alleys	**16.8**	**0.7**	**7.9**	**15.7**	**52.5**	**6.4**	**NA**	**NA**	**NA**
Multi-family Residential/Institutional	**20.7**	**11.3**	**7**	**14.6**	**42.4**	**NA**	**0.1**	**0.1**	**3.8**
Park	**0.5**	**4.4**	**1.7**	**3.3**	**78.8**	**NA**	**1.8**	**7.8**	**2.5**

* unit: %
NA- not applicable

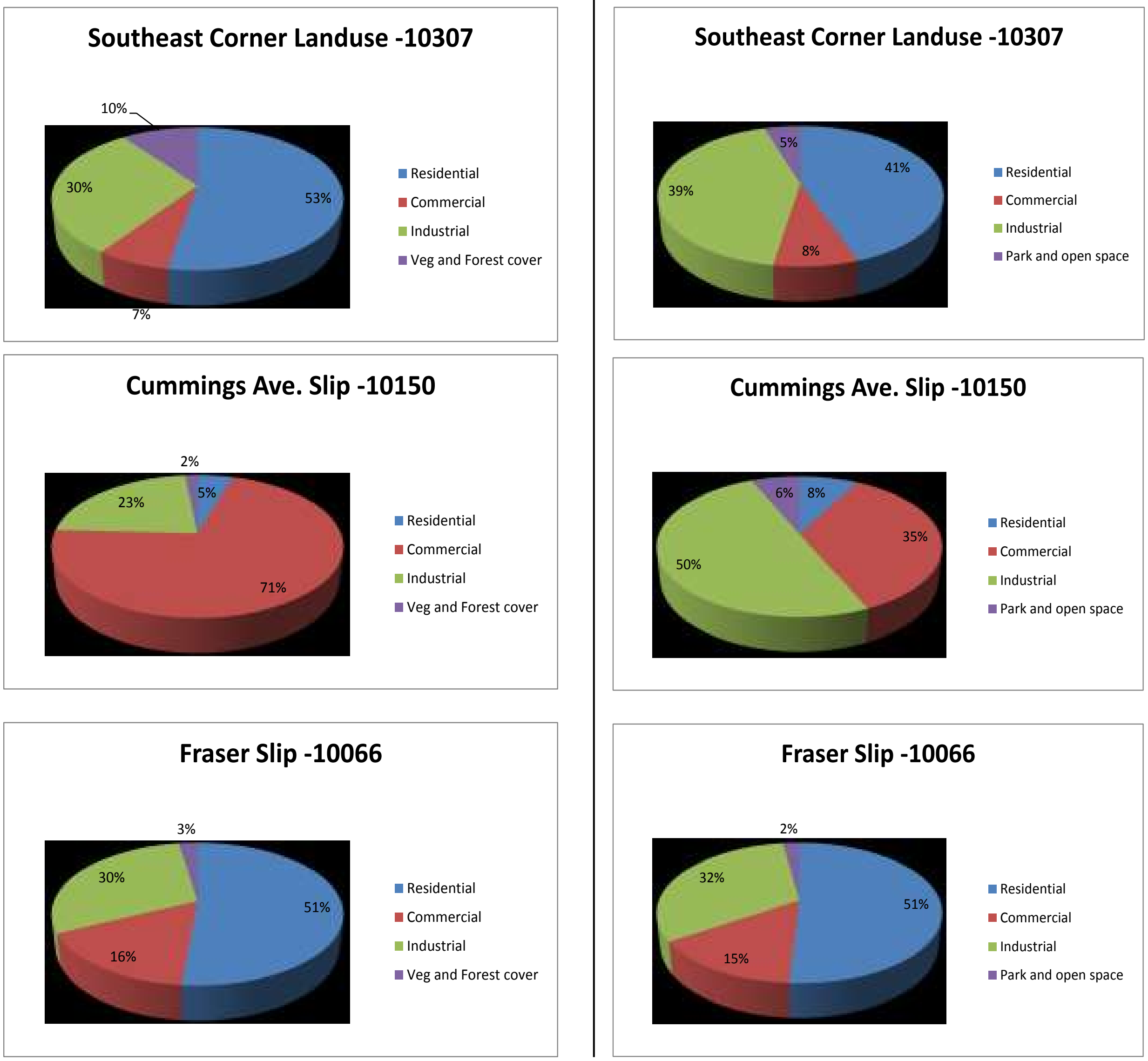
4.1.3.2 Snowmelt runoff from MS4 discharge

The City of Superior receives a significant amount of snowfall, as shown in Fig. 21. A total of 301 inches of snow fell in Superior between 1981 and 1985 [NOAA,2014]. The WinSLAMM model does not simulate snowmelt runoff assuming the runoff generated in March contains snowmelt. However, as shown in Fig. 17, in the 67 years between 1947 and 2013, there was over 50% chance of snow falling in April and May. With an average high temperature rising above the freezing point, there are possibilities of snowmelt runoff that may not be represented by WinSLAMM modeling results. Therefore, an attempt was made to calculate snowmelt runoff outside of the model.

A simple method was used to estimate the loading as a result of snowmelt. The snowfall depth was converted to a water equivalent depth. Various methods are available for estimating the snow water equivalent depth. Uncertainties may exist in various methods developed for estimating the snow water equivalent [Schmidlin, et. al., 1990 and 1995]. An average ratio of 10:1 was adapted from the studies conducted by the Minnesota Department of Transportation (MNDOT) [Shulski M. and M, Seeley, 2002 and NSCR,2014]. As a result, the cumulative snowfall amount during 1981-1985 was equivalent to 30 inches of water (6 in/yr), which is similar to the annual depth of 5.2 inches for Duluth, MN, as reported by Ellingwood, et. al, (1984). This water equivalent depth ($\mathbf{D_s}$) was divided by the total rainfall depth ($\mathbf{D_r}$) to yield a ratio $\mathbf{R_{s/r}}$ ($\mathbf{R_{s/r} = D_s / D_r}$). The result was then used to estimate mass loading from snowmelt ($\mathbf{L_{snow}} = \mathbf{L_{rain}} * \mathbf{R_{s/r}}$). A total of 12.8 ft of rainfall ($\mathbf{D_r}$) was recorded for the 5-year time period, and the snowfall water equivalent depth ($\mathbf{D_s}$) was 2.5 ft in the same period, resulting in a ratio of 0.2 ($R_{s/r}$) This value was used to estimate the total TSS and Pb loading from snowfall from the MS4 during 1981-1985.

A ---source: City's GIS database

B --- source: County's GIS database



Area (acres)		
Outfalls	**City**	**County**
Cummings Ave. Slip (OT010150)	42	58
Fraser Slip (OT010066)	85	94
SE Corner (OT010307)	21	44
Total	148	196

Fig. 23 Land use types for WinSLAMM model

Table 9. Default input concentration of TSS and Pb in WinSLAMM model

Land Use Type		Total Suspended Solids (mg/l)					
Code	Type	Residential	Institutional	Commercial	Industrial	Other Urban	Freeway
AT 1:	**Roofs**	37	33	33	30	37	NA
AT 2:	**Paved Parking**	130	130	130	250	130	NA
AT 3:	**Unpaved Parking, Driveways and Walkways**	154	154	154	154	154	NA
AT 4:	**Paved Playgrounds**	154	154	154	154	154	NA
AT 5:	**Paved Driveways**	154	154	154	154	154	NA
AT 6:	**Paved Sideways and Walks**	75	75	75	75	75	NA
AT 7:	**Large Landscaped Areas**	227	227	227	227	227	227
AT 8:	**Small Landscaped Areas**	227	227	227	227	227	16
AT 9:	**Undeveloped Areas**	16	16	16	16	16	227
AT 10:	**Other Pervious Areas**	227	227	227	227	227	154
Land Use Type		Particulate Pb (mg/kg)					
Code	Type	Residential	Institutional	Commercial	Industrial	Other Urban	Freeway
AT 1:	**Roofs**	686	639	639	151	686	151
AT 2:	**Paved Parking**	303	303	303	129	303	129
AT 3:	**Unpaved Parking, Driveways and Walkways**	180	180	180	180	180	180
AT 4:	**Paved Playgrounds**	180	180	180	180	180	180
AT 5:	**Paved Driveways**	180	180	180	180	180	180
AT 6:	**Paved Sideways and Walks**	180	180	180	180	180	180
AT 7:	**Large Landscaped Areas**	138	138	138	138	138	138
AT 8:	**Small Landscaped Areas**	138	138	138	138	138	138
AT 9:	**Undeveloped Areas**	138	138	138	138	138	138
AT 10:	**Other Pervious Areas**	138	138	138	138	138	138

4.1.3.3 Storm Water Runoff from Riparian Parcels

Direct mass loading generated by storm water runoff from riparian parcels (i.e. mass not conveyed via the MS4) was estimated using the following equation:

$$\mathbf{M}_{\mathbf{5\text{-}yr}} = \boldsymbol{D} \times \boldsymbol{A} \times \boldsymbol{C}_{ave} \qquad (2)$$

where: $\mathbf{M}_{\mathbf{5\text{-}yr}}$ = total mass loading of TSS and Pb in the 5-year time period of 1981-1985
$\boldsymbol{D}$ = rainfall depth in the WinSLAMM model or derived snowfall water equivalent depth
$\boldsymbol{A}$ = surface area of a parcel
$\boldsymbol{C}_{ave}$ = average concentration in rainfall or snowmelt

The surface area of each parcel (Fig. 24) was estimated using ArchMap 10.0. It was assumed that the runoff generated from the parcels directly discharged to the designated areas without attenuation. A portion of the shipyard property was assumed to be connected to the MS4 draining to Fraser Slip, and is not accounted for in the estimation of direct runoff.

Most of these riparian parcels are used for industrial and commercial operations, except for A1. Currently, A1 is defined as undeveloped area (City of Superior, 2014), and the concentration of Pb was assumed to be 1.3 ug/l for the analyses. Because A1 is located at the north side of the bay and did not directly discharge to the most of selected areas in study. Also, in general the average concentration of Pb in the adjacent sediment was considerably lower when compared to the opposite side. Therefore, the calculation was performed just for information and part of the quantification of mass loading. For the rest of the parcels (A2-A7), an average concentration of 49 ug/l of Pb was adopted from literature [Pitt and *et al.* , 2004] as shown in Table 10. The average TSS concentration was set at 150mg/l for all parcels, which was an average concentration for industrial and commercial lots in the input of WinSLAMM.

4.1.3.4 Storm Water Runoff from the Interstate HWY I-535

Equation (2) was also used for estimating mass loading of TSS and Pb from the Interstate HWY I-535 storm water runoff. The rainfall depth and snowfall water equivalent depth were kept the same as for runoff from the MS4. However, the surface area and concentrations of TSS and Pb in runoff were changed to reflect HWYI-535 and the typical characteristic of runoff from highways.

The area of the highway was calculated as the product of length and width. The highway was divided into three portions on the Wisconsin side: the south extent (part of A3 in Fig. 23), north extent (par of A1 in Fig. 21), and the bridge (A8 in Fig. 23). Runoff from the south extents was assumed to drain to Cummings Ave. Slip via A3 and runoff from the north extent was assumed to drain to the north side of the navigation channel in the bay without a specific location. Runoff from the bridge was assumed to drain directly to Area A8. The highway length was calculated as 970 meters (m) for each extent and 320 m for the bridge crossing the bay. The width of the extent and bridge was estimated to be 20 m, using a standard lane width of 3 m for two lanes plus the shoulder width of about 4 m in each direction. The estimated width was close to the range of 19 m to 23 m reported by the MNDOT [2012]. Surface area was then calculated by multiplying the length by the width. As a result, the highway surface area was estimated to be 18,876 m^2 (~4.7 acres) for each of the extent and 6,286 m^2 (~1.6 acres) for the bridge.

The average concentrations of 172 mg/l and 1,590 ug/l for TSS and T_Pb, respectively, were used for estimating the loading from rainfall events. These concentrations were collected from HWY I-794 in 1976-1977 as presented in Table 6. In order to assess potential loading from snowmelt, ratios derived from the data collected at the HWY I-894 station between 1999 and 2000 was developed for estimation of concentrations at the HWY I-794 because there were no winter season data collected from the I-794 station. Dividing the average concentrations in the winter season by the average concentrations in the non-winter season, a ratio of 0.6 and 2 was obtained for T_Pb and TSS, respectively. Multiplying these ratios to the average non-winter concentration at the HWY I-794 station, the average concentrations in the winter season was estimated to be 103 mg/l and 3,334 ug/l for TSS and T_Pb, respectively. The proportionally estimated concentrations were used for the mass loading estimation for the HWY I-535.

Fig. 24 Direct runoff drainage parcels (A1 to A7 are the riparian properties identifed, A8 is the area affected by runoff from HWY I-535 Bridge. Numbers in each confied area are the surface area in acres**)**

Table 10. Source area concentrations of Pb for estimating mass load from riparian parcels*

No.	Source areas	Concentration of Pb		
		T_Pb	P-Pb	Dis_Pb
		ug/l	mg/kg	ug/l
1	**Commercial parking lots**	51	320	1.7
2	**Industrial parking lots**	53	180	2.1
3	**Small landscape area**	54	250	2.8
4	**Commercial streets**	39	210	1.9
	Average (source areas 1-4)	49	240	2
5	**Undeveloped area**	1.3	48	0.0

* Data source: Pitt et. al. 2004

4.1.4 Mass loading of Pb from the background storm water runoff: 1981-1985

4.1.4.1 Mass loading from the MS4 discharge

Estimated mass loadings from WinSLAMM model simulations of the MS4 based on the county's land use coverage (Scenario I) for the period from 1981-1985 are summarized in Table 11. The MS4 was estimated to deliver, via both rainfall and snowmelt, a total Pb mass of 22 pounds (lbs) to Cummings Ave. Slip, 32 lbs to Fraser Slip, and 16 lbs to the SE Corner. The total mass for Fraser Slip may not completely account for runoff from the Fraser property, particularly on the southeast side of the slip where direct runoff has been observed circumventing the MS4 outfall (Fig. 8). Twenty percent of the total mass of Pb from rainfall runoff was assumed to load to the selected locations in snowmelt form. The amount was relatively small compared to that delivered during rainfall events. Of the total Pb delivered to these locations, roughly more than 90% was in particulate form. Fraser Slip received the largest volume of runoff (1.8x107 cft). However the concentrations of TSS and Pb in the MS4 discharge at Fraser Slip were comparable to that at Cummings Ave. Slip and the SE Corner.

To evaluate the effect of changing land use coverages by different databases, a model simulation (Scenario II) based on the City's dataset was conducted. Also in Scenario II, the industrial land use type was separated from the commercial land use type. Comparison between the two model simulation runs indicated that the total loading of Pb to Cummings Ave. Slip may increase by 24%, no change to Fraser Slip, and a 60% deduction for the SE Corner. The results are shown in Table 12. Given all the uncertainties related to model simulation, this variation is accepted and Scenario I was used for further analyses; however, the change on total mass loading for long-term will be also briefly discussed later.

4.1.4.2 Mass loading from riparian parcels and Interstate HWY I-535

Estimated mass loadings from riparian parcels and Interstate Hwy 535 were derived using Equation 2, for the time period from 1981–1985, and are summarized in Table 13. According to these estimates, the majority of mass loading from the riparian parcels to the bay was a result of

Table 11. Predicted Pb loading to the selected locations from MS4 (1981-1985)*

Outfall Locations	Storm Water Runoff Volume		TSS			Pb						Total Pb
	Rainfall	Snowmelt	Model-rainfall		Estimate - snowmelt	P_Pb Model-rainfall		Dis_Pb Model-rainfall		Total mass Model - rainfall	Total mass Estimate - snowmel	
	(cft)	(cft)	conc (mg/l)	mass (lb)	mass (lb)	conc (ug/l)	mass (lb)	conc (ug/l)	mass (lb)	mass (lb)	mass (lb)	(lb)
Cummings Ave. Slip	1.23E+07	2.46E+06	161	123,569	24,714	21	17	2	1	18	4	22
Fraser Slip	1.83E+07	3.65E+06	149	170,000	34,000	22	25	2	2	27	5	32
SE Corner	8.79E+06	1.76E+06	150	82,108	16,422	22	12	2	1	13	3	16

* Loading of Pb from rainfall storm water runoff was simulated by using the WinSLAMM model based on the land use coverage database on the County's GIS database.(http://www.ci.superior.wi.us/index.aspx?nid=474)

Table 12. Comparison of WinSLAMM model results with varying land use coverage:1981-1985

Outfall Locations	Storm Water Runoff Volume-Scenario II	TSS				Pb						
						P_Pb		Dis_Pb		Total mass (rainfall+snowmelt)[(1)]		
	Rainfall	Model-rainfall Scenario I		Model-rainfall Scenario II		Model-rainfall Scenario II		Model-rainfall Scenario II		Model - Scenario I	Model - Scenario II	Relative difference
	(cft)	conc (mg/l)	mass (lb)	conc (mg/l)	mass (lb)	conc (ug/l)	mass (lb)	conc (ug/l)	mass (lb)	mass (lb)	mass (lb)	%
Cummings Ave. Slip	1.22E+07	161	123,569	113	86,396	27	21	2	2	22	27	+24
Fraser Slip	1.72E+07	149	170,000	137	147,228	23	25	2	2	32	32	0
SE Corner	3.79E+05	150	82,108	142	33,566	22	5	0.4	0.4	16	6	-60

(1) The total mass = mass generated via rainfall and snowmelt. The amount from snowmelt is 20% of the amount from rainfall.

Table 13. Estimates of mass loading from riparian parcels and Interstate HWY I-535

Parcel ID-> runoff receiving area	Area	Volume		1981-1985			
				TSS[1]		Pb[1]	
		Rainfall	Snowmelt	Rainfall	Snowfall	Rainfall	Snowfall
	(acre)	($x10^6$cft)	($x10^6$cft)	(lb)	(lb)	(lb)	(lb)
A1->Northside	36	200	111	187,228	36,711	1.6	0.3
A2->Hughitt Ave. Slip	9	50	28	46,807	9,178	15.3	3.0
A3->Hughitt Ave. Slip (2/3)	10	56	31	34,672	6,798	10.2	2.0
A3->Cummings Ave. Slip (1/3)	10	56	31	17,336	3,399	5.7	1.1
A4->Cummings Ave. Slip	5	28	15	26,004	5,099	8.5	1.7
A5-> Fraser Slip (1/8)	14	78	43	9,101	1,785	3.0	0.6
A6->SE Corner	3	17	9	15,602	3,059	5.1	1.0
A7->SE Corner	3	17	9	15,602	3,059	5.1	1.0
HWY-Bridge->A8[2]	2	0.9	0.2	10,314	1,186	2.7	1.1
HWY-extent ->Cummings Ave. Slip[2]	5	2.8	0.6	31,265	3,561	8.2	3.3

(1) Values under "Area" and "Volume" are the total areas and volume for each parcel A1 through A8. Runoff from the parcels was assumed to drain to different areas, as follows: A1 drains to north side of the bay, A2 to Hughitt Ave. Slip, One third of A3 to Cummings Ave. Slip and two thirds to Hughitt Ave. Slip, A4 to Cummings Ave. Slip, One eighth of A5 to Fraser Slip and the rest to Baxter Ave. Embayment (which is not part of the analyses) and the navigation channel, A6 and A7 to the SE Corner (Unit 1)

(2) Concentration of Pb for snowmelt runoff from HWY I-535was based on a ratio derived from data obtained from HWY I-894. Based on the data collected from the HWY I-894 station, a ratio of 2 was obtained by dividing the average observed concentration of 65 ug/l in the winter season to 31 ug/l in the non-winter season for the time period of 1990-2000 (Table 7). The concentration of Pb in runoff from HWY I-794 in winter season in 1976-77 was then compute by multipling the concentration observed in the non-winter season by 2. A similar approach was applied to TSS.

rainfall runoff and is influenced by the land use type and size of the catchment area. The average mass loading from source areas A2 to A7 was about 2 lb/acre and about 2.5 lb/acre from the Interstate HWY I-535. Direct runoff from riparian areas was estimated to deliver a total Pb mass of 31 lbs to Hughitt Ave. Slip, 25 lbs to Fraser Slip, 4 lbs to Cummings Ave. Slip, 12 lbs to the SE Corner, and 4 lbs to Area A8 over this five year period. The estimate for Fraser Slip does not include potential loading from the portion of the shipyard to the south of Fraser Slip since a simplifying assumption was made that this area drained through the MS4 outfall.

Note that the estimation for runoff from HWY I-535 was based on data collected from I-794 and I-894 in Milwaukee, which may cause the results to be biased high.

4.2 Atmospheric Deposition of Pb

Atmospheric deposition includes indirect and direct deposition, as discussed earlier. The contribution from indirect deposition to Howards Bay was assumed to be reflected in the background storm water runoff. Direct deposition includes fallout to surface water in the forms of precipitation, in dust, or simply due to gravity. Dry deposition of Pb was about 13% to 20% of the total flux of Pb according to the data collected in 1997 and 1998 for Lakes Huron and Ontario [EC and USEPA, 1998] but was reported to be almost equal in the 1970s by Gatz [1975]. The fate and transport of airborne contaminants is complicated [Sanderson, *et al.* 1985]. The flux of Pb varies in space and time. The flux of Pb to water bodies has been decreasing significantly since the 1980s [Gatz *et al*., 1989; Sweet *et al*. 1998; and EC and USEPA, 2000, 2005]. This study used the data as cited in the literature and employed a simple method to estimate the direct deposition of Pb as expressed in Equation (3):

$$\mathbf{M}_{\textbf{5-yr-air}} = \boldsymbol{F_{Pb}} \times \boldsymbol{A} \qquad (3)$$

where: $\mathbf{M}_{\textbf{5-yr-air}}$ = total mass loading of Pb from atmospheric deposition in the 5-year time period of 1981-1985;

$\boldsymbol{F_{Pb}}$ = atmospheric flux of Pb, which is the mass of Pb that deposits to a unit surface area in a unit time;

$\boldsymbol{A}$ = surface area of a specific location

Table 14 summarizes the fluxes of Pb to the Great Lakes. As the table shows, fluxes of Pb to Lake Superior decreased from 7.8 ug/m^2/d to 1.7 ug/m^2/d between 1986 and 1994. Similar decreasing trends were observed for Lakes Huron and Ontario from 1994 to 2005.

The decreasing trend of Pb fluxes to the Great Lakes can be attributed to the decreasing of concentration of Pb in the atmosphere (Fig. 10), which is believed to be mainly a result of the reduction of Pb in gasoline, regardless of the increase of vehicles on the road. After Pb in gasoline was phased out starting in the early 1980s, the concentration of Pb decreased significantly. By 1992, the national average concentration of Pb was 0.3 ug/m^3 (Table 14).

According to researches [USEPA, 2000], fluxes of contaminants near urban areas were higher than in rural areas. However, the reported value of 0.2 ug/m^2/d in 2000 in areas affected by Chicago [USEAP,2000] was less than the values for Lake Huron(3.9 ug/m^2/d) and Lake Ontario (5.0 ug/m^2/d) in the same year (Table 14). Additionally, since 2002, the Integrated Atmospheric

Table 14. Atmospheric flux of Pb

Year	Lake Huron[a] T_Pb ($ug/m^2/d$)	Lake Ontario[a] T_Pb ($ug/m^2/d$)	Lake Superior[a][b] T_Pb ($ug/m^2/d$)	Urban, MN[c]	Chicago Area[b] T_Pb ($ug/m^2/d$)	Regristered vehicle x10^8	Average conc[a] T_Pb (ug/m^3)	Pb in gasoline[d] (g/gal)
1940			11[e]			0.3		2-4
1969							0.9(0.5)	
1970			39[e]			1.1		4, 2.5[c]
1973								2.2
1975			21-26[f]	26[c]		1.4	0.9	1.7
1979							0.2[c]	0.5
1980			13[e]			1.6	1.6	0.5[f], 1.0[c]
1981				18			0.1[c]	
1982				13			0.04[c]	
1983				10			0.02[c]	
1985								0.5
1986			7.8			1.8	0.7	0.1
1988			7.7			1.8	1.1	
1992			2.2			1.9	0.3	
1994	2.2	3.6	1.7			2.0	0.4	
1995	3.7	5.4				2.1	0.3	
1996	3.7	5.4				2.1	0.3	0
1997	4.7	5.3				2.1	0.2	
1998	2.2	4.8				2.2	0.2	
1999	2.4	3.2				2.2	0.2	
2000	3.9	5.0			0.2	2.3	0.2	
2001	1.8	5.7				2.4	0.3	
2002	1.6	4.3				2.3	0.2	
2003	1.6	4.2				2.4	0.2	
2004	1.6	3.3				2.4	0.3	
2005	1.7	2.2				2.5	0.3	

(a) Source: All data were from EC and US EPA (2000), otherewise, as noted. Average Pb concentration in the air for 1969 was from Winchester and Nifong (1971). The concentration in parenthesis was for Chicago and Milwaukee.)

(b) Source: EC and US EPA (2005)

(c) Urban MN: results from studies conducted in Minnesota by Eisehreich et. al. 1986

(d) Source: USEPA (**http://www.epa.gov/airtrends/lead.html**); otherwise, as noted.

(e) When there were not literature values, the flux of Pb to Lake Superior was estimated as follows:

1980: $Flux_{1980} = Average\ (Flux_{1986}\ and\ Flux_{1988}) \times C\text{-}Pb_{1980} / Average\ (C\text{-}Pb_{1986}\ and\ C\text{-}Pb_{1988})$

1970: $Flux_{1970} = Flux_{1980} \times Average\ (G\text{-}Pb_{1970}\ through\ G\text{-}Pb_{1979}) / G\text{-}Pb_{1980} \times N\text{-}V_{1970} / N\text{-}V_{1980}$

1940: $Flux_{1940} = Flux_{1970} \times (N\text{-}V_{1940} / N\text{-}V_{1940})$

Where, $Flux_{year}$ – flux for the year; $C\text{-}Pb_{year}$ – national average total lead in the air in the year; $G\text{-}Pb_{year}$ – Pb in gasoline in the year; $N\text{-}V_{year}$ - number of vehicles registered

(f) Source: derived from IJC (1977)

Deposition Network (IADN) Duluth Station has not detected Pb in the air [EC and USEPA, 2013]. Given these conditions, the total mass of Pb from atmospheric deposition to Howards Bay for the time period of 1981-1985 was interpreted based on the reported concentration of Pb in the air, vehicle flow, and the fluxes to Lake Superior.

The reported Pb fluxes between 1986 and 1988 and airborne Pb concentration in 1980 provided the basis of estimating Pb flux for the time period of 1981-1985. First, a ratio was developed by dividing the concentration of Pb in 1986 and 1988 to that in 1980. Then, an average flux value of 1986 and 1988 was multiplied by the ratio to yield the flux in 1980. As a result, the flux of Pb in 1980 was estimated to be 13 ug/m^2/d (Table 14) and applied to the time period of 1981-1985. Using the similar approximation method, the estimated flux of Pb for 1980 was proportionally scaled for the fluxes in 1970 and 1940 by using the comparison of Pb in gasoline and number of registered vehicles (Table 14). The reasons to use these variables were that no airborne concentrations were available and emission from vehicles was assumed to be the predominant airborne Pb source. In terms of the basis of choosing 1940 and 1970 as the significant years for the record of Pb flux, there are two reasons: 1) historically, year 1970 is critical because the amount of Pb in gasoline was stable between 1940 and 1970, but soon after 1970, it decreased sharply (Table 14 and Fig. 9) and 2) presumably, the mass of Pb present in sediment now has accumulated from the early 1940s. For convenience purpose, 1940 was selected as a date for evaluation.

As a result, the annual mass of airborne Pb entering five selected locations was estimated to range from 0.04 lb/yr (0.02 kg/yr) to 0.26 lb/yr (0.12 kg/yr) as summarized in Table 15. Based on this study, Area A8 received the most mass of airborne Pb at about 1.5 lbs compared to the other four selected locations due to its relatively larger area. Less than 1lb of Pb was deposited in the other four locations.

4.3 Total Mass of Pb from Background Storm Water Runoff and Atmospheric Deposition: 1981-1985

The results from mass loading analyses for the background storm water runoff and atmospheric deposition were combined as the total loading from these two sources to the five selected locations for the time period of 1981-1985, and are summarized in Table 16. As shown in the table, the total Pb input to Cummings Ave. Slip, Fraser Slip, and the SE Corner ranged from 29 to 50 lbs, with the largest amount contributed by the MS4, and then followed by the direct input from riparian parcels. Because there are no major outfalls located in the Hughitt Ave. Slip and Area A8, the MS4 contribution was assumed to be zero in these two locations. Direct runoff from riparian parcels contributed about 30 lbs to Hughitt Ave. Slip over the five-year period. No direct input from riparian parcels was applied to Area A8. The contribution from direct atmospheric deposition was small for the five locations with the maximum amount of 1.5 lb to Area A8. Highway storm water runoff contributed about 12 lbs of Pb to Cummings Ave. Slip and 4 lbs to Area A8.
The estimated total mass loading from the MS4 was based on the land use type obtained from the County's GIS database. If the City's database was used, the total mass of Pb will increase by 5 lbs for Cummings Ave. Slip but decrease to 19 lbs for the SE Corner. The variation is well accepted and no further uncertainty analyses were conducted.

Table 15. Atmospheric deposition of Pb for the time period of 1981-1985*

Location	Area	Annul deposition	Mass	
	acre	kg/yr	kg	lb
Hughitt Ave. Sli	2.65	0.05	0.3	0.6
Cummings Ave.	1.7	0.03	0.2	0.4
Fraser Slip	0.9	0.02	0.1	0.2
SE Corner	2.5	0.05	0.2	0.6
Area A8	6.4	0.12	0.6	1.5

* Atmospheric deposition flux was kept constant at 13.7 ug/m^2/d (rounded to 14 ug/m^2/d)

Table 16. Summary of mass loading to the selected locations in Howards Bay (1981-1985)

Locations	TSS				Total TSS
	MS4	Riparian Parcels	Highway	air deposition	
	(lb)	(lb)	(lb)	(lb)	(lb)
Hughitt Ave. Slip	-	97,455	-	NA	97,455
Cummings Ave. Slip	148,283	51,838	34,826	NA	234,947
Fraser Slip	204,000	29,548	-	NA	233,548
SE Corner	98,530	37,323	-	NA	135,853
Area A8	-	-	46,326	NA	46,326

Location	Pb				Total Pb
	MS4	Riparian Parcels	Highway	air deposition	
	(lb)	(lb)	(lb)	(lb)	(lb)
Hughitt Ave. Slip	-	30	-	0.6	31
Cummings Ave. Slip	21	17	12	0.4	50
Fraser Slip	32	4	-	0.2	36
SE Corner	16	12	-	0.6	29
Area A8	-	-	4	1.5	6

4.4 Allocation of Sources for Pb in Sediment

The allocation of Pb sources in sediment was based on a mass balance approach expressed as $M_{sed} = L_b + L_{air}, + L_{ii}$, (equation 1) and was limited to the five Howards Bay locations. Previous sections discussed the methodologies and results of the estimation of L_b and L_{air} for the time period of 1981 -1985. This section will present the analyses for a 74 year time period between 1940 and 2013 based on Pb in sediment (M_{sed}). The time domain of 1940 to 2013 was determined primarily by the historical sediment deposition records as discussed in Section 3. The bottom of the soft sediment was assumed to have been deposited in the early 1940s because the nautical chart from 1943 is the earliest showing a similar configuration of the bay to that of the present day. Other factors considered included the history of the automobile industry and associated gasoline usage, due to its significant effect on Pb concentrations in the environment. Beginning in the 1940s, vehicle flow increased significantly, as evident from the increase in the number of registered vehicles (Fig. 8). Therefore, it was reasonable to set the beginning year in 1940. The ending date set in 2013 was chosen because the FFS study was based on the latest samples, which were collected in 2013.

4.4.1 Estimating Pb in sediment in the selected locations

The mass of Pb in sediment in Hughitt Ave. Slip, Cummings Ave. Slip, Fraser Slip, the SE Corner (Unit 1), and Area A8 was calculated based on the average concentration and volume of soft sediment in depositional zones. The deposition zones were defined according to the sediment management units identified in the FFS (ARCADIS, 2015). It was assumed that all particles entering the selected location will deposit in the area represented by the management units in each location due to a focusing factor. Subsequently, the mass of Pb in sediment was calculated according to equation (4).

$$\mathbf{M_{sed}} = \Sigma \mathbf{V}_i * \mathbf{C}_i * \rho \quad (i = 1, 2,.. n) \qquad (4)$$

Where, $\mathbf{M_{sed}}$ = total mass of Pb in each selected location;

$\mathbf{V}_i$ = volume of soft sediment in the ith management unit;

$\mathbf{C}_i$ = average concentration of Pb in ith management unit; and ρ = bulk density, which is assumed to be $1 g/cm^3$

Table 17 summarizes the mass of Pb in the selected locations. Also included in the table are the parameters used for calculating the mass. As shown in the table, a total of 2,392 lbs of Pb is present in Hughitt Ave. Slip, 2,230 lbs in Cummings Ave. Slip, 2,810 lbs in Fraser Slip, 5,290 lbs in the SE Corner, and 2,279 lbs in Area A8. These masses of Pb are assumed to be input from nonpoint sources, including potentially historical industrial discharges and atmospheric deposition with anthropogenic origins between 1940 and 2013. Different from other locations, Pb in Area A8 sediment may have accumulated between 1963 and 2013 and could come from other portions of the bay as a result of redistribution. Note that the estimated timeline for sediment deposited in Hughitt Ave. Slip and Area A8 may carry high uncertainties due to dredging and redistribution of sediment in the bay. Therefore, the allocation of Pb to the identified sources based on mass balance approach was tentative for Hughitt Ave. Slip and not conducted for Area A8.

Table 17. Estimated mass of Pb in sediment

Location	Management Unit(1)	Area	Thickness of sediment	Volume(a)	Average Conc of T_Pb	Mass			
						Total Solids(b) (ρ=1 g/cm^3)		T_Pb	
		acre	ft	cyd	mg/kg	kg	lb	Kg	lb
Hughitt Ave. Slip	Unit 29	0.57	1	930	57	7.1E+05	1.6E+06	41	90
	Unit 28	0.24	1	390	36	3.0E+05	6.6E+05	11	24
	Unit 27	0.85	2	2700	214	2.1E+06	4.5E+06	443	974
	Unit 26	0.99	7	11000	71	8.4E+06	1.9E+07	593	1,304
	Total	**2.65**	**NA**	**15,020**	**NA**	**1.1E+07**	**2.5E+07**	1,087	**2,392**
Cummings Slip	Unit 19a	0.51	1	826	33	6.3E+05	1.4E+06	21	46
	Unit 19a	0.57	3	2,780	168	2.1E+06	4.7E+06	356	784
	Unit 19a	0.48	1.5	1,165	156	8.9E+05	2.0E+06	139	305
	Unit 19d	0.15	8	1,970	331	1.5E+06	3.3E+06	498	1,095
	Total	**1.71**	**NA**	**6,741**	NA	**5.2E+06**	**1.1E+07**	**1,014**	**2,230**
Fraser Slip	Unit 10	0.45	4	**2,893**	323	2.2E+06	4.9E+06	715	1,573
	Unit 11	0.44	3	**1,764**	417	1.3E+06	3.0E+06	562	1,236
	Total	**0.89**	**NA**	**4,657**	**NA**	**3.6E+06**	**7.8E+06**	**1,277**	**2,810**
SE Corner	**Unit1**	**2.6**	**4**	**4,657**	**194**	**1.3E+07**	**2.8E+07**	**2,496**	**5,490**
Area A8(c)	**-**	**5**	**5**	**30,837**	**42**	**3.1E+07**	**6.8E+07**	**1,036**	**2,279**

(a) The management units are defined in the FFS report and the volume is adapted from the FFS report (ARCADIS,2015) assuming the management units represent depositional zones.

(b) ρ= bulk density

(c) For Area A8, the area was calcualted using GIS10.0. Sediment thickness in this area is assumed to be 5 ft based on the multiple cores as listed in Table 3.

cyd: cubic yard

NA: not applicable

4.4.2 Total Mass of Pb from Background Storm Water Runoff and Atmospheric Deposition:: 1940-2013

Results of the mass loading for the time period of 1981-1985 were extrapolated to estimate the total mass of Pb loading to three locations: Cummings Ave. Slip, Fraser Slip, and the SE Corner, with reasonable certainty in the sediment record for the time period of 1940 to 2013. Although the estimates for 1981-1985 may represent an average loading from the background storm water runoff and atmospheric deposition for 74 years, it is acknowledged that uncertainties exist. A basic sensitivity analysis was conducted with regard to atmospheric deposition of Pb. Results from two estimation methods were used: one was to use a constant flux based on 1981-1985 results and the other used variable fluxes. Table 18 summarizes the comparative results. Comparison of total mass of Pb derived from using these two methods showed that the constant flux approach yielded about 10% higher mass loading from the air (Table 18). The variation is considered acceptable for this study. However, to be conservative, the higher amount of mass, resulting from the constant flux method was used for further mass balance analyses.

Table 19 provides a summary of the estimated total mass loading of Pb from background storm water runoff and atmospheric deposition over the 74 years based on two major assumptions:

- Upon settling of Pb laden particles in the selected locations, the materials were integrated into soft sediment and remained in local places, not available for further transport in the bay.
- There is no loss of Pb through biological pathways.

According to the estimation, the total mass loading of Pb from the background storm water runoff and atmospheric deposition over the 74 years ranged from 84 lbs in Area A8 to 740 lbs in Cummings Ave. Slip. As a reference, Hughitt Ave. Slip and Area A8 were included in the estimation of total mass loading in the 74-year period but not included in source allocation with the reason given above.

After $\mathbf{M_{sed}}$**,** $\mathbf{L_b}$**,** and $\mathbf{L_{air}}$ were estimated, the incidental input ($\mathbf{L_{ii}}$) was solved according to Equation (1). Subsequently, the relative contribution of Pb by these sources was evaluated. The results are summarized in Table 20 and displayed in Fig. 25. The evaluation could only be applied to three locations with reasonable certainty in the sediment record: Cummings Ave. Slip, Fraser Slip, and the SE Corner. Based on the mass balance calculation, the results showed that the loading of Pb from background storm water runoff and air deposition combined only accounted for 10% to 26% of the Pb present in the sediment inventory of Cummings Ave. Slip, Fraser Slip, and the SE Corner. The overwhelming majority, or 74% to 90% of the Pb present in these locations, could be attributed to incidental input. The incidental inputs that may have contributed to Pb in sediment and caused a high level include, but are not necessarily limited to, historic practices for handling waste and wastewater generated from marine and shipbuilding operations, spills, illicit discharges to the MS4, and other uncontrolled practices that were commonplace prior to conscious environmental stewardship practices. The results also lead to a conclusion that the mass loading of Pb from typical storm water runoff alone or combined with direct atmospheric inputs will not cause Pb concentration in Howards Bay to be elevated to the levels detected in sediment cores collected from the 1990s to 2013 (Note: a maximum concentration of 2,700 mg/kg was detected in 2015 after the calculation was completed under this study).

Table 18. Comparison of atmospheric deposition of Pb based on constant and variable fluxes (1940-2013)

Estimation method	Time period	Fluxes of Pb	Depostion of Pb				
			Hughitte Ave. Slip	Cummings Ave. Slip	Fraser Slip	SE Corner	Area A8
		$ug/m^2/d$	lb	lb	lb	lb	lb
Variable fluxes[a]	1940-1980	26	9.1	5.8	3.0	8.9	21.9
	1980-1990	12	1.0	0.6	0.3	1.0	2.4
	1990-2013	2	0.4	0.3	0.1	0.4	0.4
	Total		**10.5**	**6.8**	**3.5**	**10.3**	**24.7**
Constant rate [b]	1981-1985	14	**8.3**	**5.4**	**2.8**	**8.1**	**20.0**

[a] The variable fluxes, derived from the report (Hoff et. al., 1994) were adopted for the time period of 1990-2013. However the flux may have decreased since 1994 because Pb was not detected in the air at Duluth after 2002 (USEPA, http://www.epa.gov/airtrend/lead.html) . Flux for the decade of 1980-1990 was estimated based on the average values for 1980 through 1988 as listed in Table 13. Flux for time prior to 1980 was first estimated for two different eras:1970-1980 and 1940-1970. The results for these two time periods did not differ greatly (26 $ug/m^2/d$ for 1970-1980 and 25 $ug/m^2/d$ for 1940-1970); therefore, the higher value for the time period of 1970-1980 was used for time prior to 1980.

[b] A constant flux of 14 $ug/m^2/d$ was used, the same for the estimation of Pb deposited in 1981-1985.

Table 19. Total loading of Pb from storm water runoff and atmospheric deposition (1940-2013)

Location	**Pb**				
	Loading from MS4	**Loading from Riparian Parcels**	**Loading from HWY I-535**	**Loading from Atmospheric Deposition**	**Total**
	(lb)	(lb)	(lb)	(lb)	(lb)
Hughitt Ave. Slip	NA	451	NA	10	462
Cummings Ave. Slip	312	251	170	7	740
Fraser Slip	474	53	NA	4	530
Southeast Corner	237	180	NA	10	428
Area A8	NA	NA	56	25	82

Table 20. Source allocation for Pb in sediment at the selected locations during the time period of1940-2013

Location	**Estimated Total Pb from Background Storm Water Runoff and Atmospheric Deposition[(1)]**	**Sediment Inventory**		**Estimation of Potential Incidental Input[(2)]**
		Pb	**Solids**	
	(lb)	(lb)	(lb)	(lb)
Hughitt Ave. Slip	462	2,230	2.5E+07	NA
Cummings Ave. Slip	740	2,810	1.1E+07	2,070
Fraser Slip	530	5,490	7.8E+06	4,961
Southeast Corner	428	2,392	2.8E+07	1,964
Area A8	82	2,855	6.8E+07	NA

(1) Mass loading from MS4 was based on Scenario I
(2) NA: not analyzed

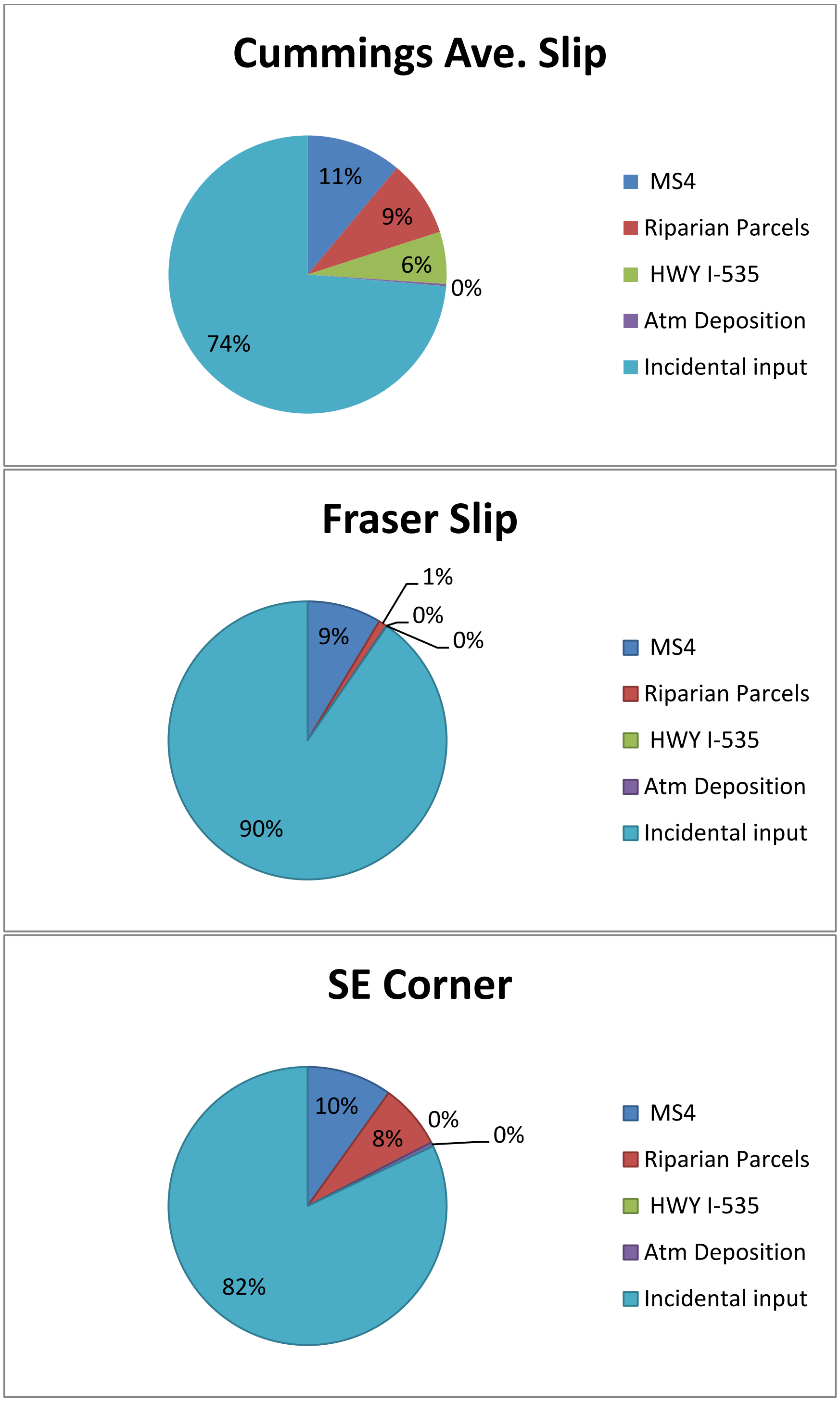


Fig. 25 Percent contribution of Pb from the identified sources to the sediment in the selected locations

4.5 Prediction of Pb in sediment post remediation

To assess the potential for recontamination of sediments, an attempt was made to estimate the concentration of Pb in soft sediment after the proposed remedial action in the depositional zones of the selected locations. The prediction was based on four assumptions:

1) all incidental input will be eliminated in the future and the loading from background storm water runoff and the atmospheric deposition will be the only sources contributing to Howards Bay.
2) the same amount mass of Pb as estimated for 1940-2013 will deposit to these selected locations after remediation
3) the future amount of soft sediment will accumulate to the same thickness and extent as in the present condition
4) no mixing between residual sediment with future deposited sediment

The predicted average concentration of Pb in sediment at the selected locations is presented in Table 21. As shown in the table, the average concentration was estimated to range from 1mg/kg to 68 mg/kg. The predicted Pb concentration of over 60 mg/kg for sediments in Fraser and Cummings Ave. Slips may be slightly elevated compared to a pristine-nonurban condition, but is well below the preliminary remedial goal of 83 mg/kg identified in the FFS by stakeholders. The lowest concentration will be at Area A8 although this estimate is tentative because the area is subject to deposition of sediment transported from other locations in the bay, and disturbed by navigation maintenance dredging.

Potentially, the predicted concentration may be biased high because air deposition rates are expected to continue to decline and the implementation of best management practices by the City of Superior and industries in the watershed are also expected to further reduce loading from these nonpoint sources compared to levels in the period of record used for this analysis.

4.6 Prediction of PAHs and Tributyltin in sediment post remediation

PAHs and tributyltin were not evaluated extensively as part of the study. A limited evaluation was conducted as discussed in Section 3. Concentrations of these contaminants in sediment post remediation were tentatively predicted based on the monitoring data collected from MS4 outfalls by the City of Superior in 2013 and 2014. Although PAHs are ubiquitous in the environment and recent studies have revealed that PAHs are high in runoff from sealed asphalt pavement [Crane, 2015], the concentration of PAHs detected in the storm water runoff from the MS4 were relatively low. It ranged from no detection to 0.9 ug/l of total PAHs, which is the sum of 16 priority pollutant compounds. To be conservative, the maximum value of these monitoring data was used to for estimating the future condition. The same assumptions as for prediction of Pb applied to PAHs except for that the atmospheric deposition was assumed to be negligible. As a result, the average concentration of PAHs in sediment was predicted to range from 0.3 to 2.3 mg/kg as summarized in Table 22, which was much lower than the concentrations present in sediment now. The current sediment contains PAHs up to 50 mg/kg in these three locations. Therefore, it is concluded that after remediation the MS4 discharge will not cause recontamination to an unacceptable level of PAHs in these selected locations.

Table 21. Predicted average concentration of Pb in the sediment after remediation

Locations	Total Loading from background storm water runoff and Air deposition	Total solids	Predicted concentration
	(lb)	(lb)	(mg/kg)
Hughitt Ave. Slip(1)	463	2.5E+07	18
Cummings Ave. Slip	740	1.1E+07	65
Fraser Slip	530	7.8E+06	68
Southeast Corner	429	2.8E+07	15
Area A8	84	6.8E+07	1

Available information on organotin usage provided by the current landowners adjacent to Hughitt Ave. Slip indicates that there are no known or suspected on-going sources of organotin compounds or mercury (which is another pollutant of concern in sediment from the slip). Other than the incidental input, it is believed that the contribution of organotin from background storm water runoff and atmospheric deposition will not result in elevating sediment concentrations to the current levels following remedial action. While an episode of scraping and repainting of an ocean-going vessel docked at a grain loading facility in Duluth-Superior harbor is apparent in the 1997 Minnesota Public Television documentary titled, *Working Waterfront: A Harbor Portrait*, it is unknown how common these practices were in the past. However, it is expected that such uncontrolled activities no longer occur due to the implementation of best management practices for environmental health. Furthermore, incidental inputs of organotin from vessels are expected to continue to decline, if not be eliminated entirely, through the 2008 global ban on the use of organotin compounds in antifouling systems (i.e. AFS Convention, IMO 2001), and the U.S. Coast Guard implementation of this international convention under Coast Guard–Commercial Vessel Compliance Policy Letter 12-08, which became effective on November 21, 2012. While other incidental inputs of organotin are possible, such as from "black market" uses of antifouling paints on noncommercial vessels or usage as a coating in heat exchange tubes, they are not expected to occur to an appreciable extent within the project area. So long as unpermitted spills, which are subject to regulatory enforcement, do not directly impact the study area, recontamination is unlikely to substantially diminish benefits of cleanup of sediments from the bay (ARCADIS 2015).

Table 21. Predicted average concentration of PAH in sediment as a result of MS4 contribution at selected locations after remediation*

Location	Runoff Volume (1981-1985)		PAH		Total loading (1981-1985)	Total loading (1940-2013)	Solids in sediment	Average PAH concentration in sediment - nonpoint source only
	Rainfall	Winter	MS4 Outfall					
	(cft)	(cft)	conc (ug/l)	mass (lb)	(lb)	(lb)	(lb)	(mg/kg)
Cummings Ave. Slip	1.23E+07	2.46E+06	0.9	0.8	0.8	12	1.1E+07	1.1
Fraser Slip	1.83E+07	3.65E+06	0.9	1.2	1.2	18	7.8E+06	2.3
Southeast Corner	8.79E+06	1.76E+06	0.9	0.6	0.6	9	2.8E+07	0.3

* based on data collected from outfalls in 2013 and 2014

5. CONCLUSIONS

This source evaluation study identified the relevant sources which contribute to sediment contamination in Howards Bay, quantified the Pb contribution to sediment from these sources, and predicted post remediation concentrations of Pb and PAHs in sediment as a result of the loading from potential sources. The potential sources in the past and future are background storm water runoff , air deposition, and incidental input. The background storm water runoff includes sources conveyed via MS4 discharges, and direct runoff from riparian parcels and Interstate HWY I-535. Incidental input includes waste and wastewater generated from marine operation, spills, illicit connections, and other uncontrolled pathways. The review of concentrations in sediment in Hughitt Ave. Slip, Cummings Ave. Slip, Fraser Slip, the SE Corner, and Area A8, indicate that contamination most likely peaked in the 1950s to 1970s prior to conscious environmental stewardship practices. The compiled monitoring data showed that concentration of Pb in storm water runoff and in the air is decreasing from the 1970s. Mass balance analyses of Pb in sediment concluded that the background storm water runoff and air deposition contributed less than 30% of Pb to the selected locations in the past. The most significant sources were incidental inputs including waste and wastewater generated from marine operation, spills, illicit connections to the MS4, and other uncontrolled practices. These incidental inputs continue to be reduced with the implementation of storm water management and pollution prevention programs that have been implemented since the 1990s. After contaminated sediment is remediated, it is believed that the background storm water runoff and atmospheric deposition will not contribute significant amounts of Pb to cause recontamination to sediments. It is also believed that the best management practices implemented by municipalities and industries, along with the global ban of organotin compounds as an anti-fouling system for vessels, will also reduce loading of other contaminants. Therefore, it is unlikely sediment will be recontaminated to a level of concern after remediation. Recontamination is unlikely to substantially diminish benefits of cleanup of contaminated sediments in the bay.

REFERENCES

Alexander R. and S. Smith (1988). Trends in Lead Concentrations in Major U.S. Rivers and Their Relation to Historical Changes in Gasoline-Lead Consumption. *Water Resource Bulletin, American Water Resources Association Vol. 24 (3):557-569*

ARCADIS (2015). Focused Feasibility Study for Sediment Cleanup in Howard's *Bay*, *Superior, Wisconsin*. Prepared for USEPA GLNPO and Non-Federal Sponsor Project Partners.

Bannerman, R. T., Legg A. D., and S. R. Greb, 1996. *Quality of Wisconsin Stormwater, 1989-94.* USGS, Open-file report 96-458.

Crane, J. L., 2014. Source Apportionment and Distribution of Polycyclic Aromatic Hydrocarbons, Risk Considerations, and Management Implications for Urban Stormwater Pond Sediments in Minnesota, USA. *Archives of Environmental Contamination and Toxicology.* Volume 66(2):176-200.

Elsenreich, S. J., Metzer, N. A., and N. R. Urban, 1986. Response of atmospheric lead to decreased use of lead in gasoline. *Environ. Sci. Technol*. **20**(2):171 - 174

Brown, E., Caraco, D., Pitt, R. 2004. *Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments*. Office of Water and Wastewater, USEPA, Washington D.C. Available: http://water.epa.gov/polwaste/npdes/stormwater/upload/idde_manualwithappendices.pdf

City of Superior, *An historic look at wastewater treatment in Superior*. Available on: **www.ci.superior.wi.us/esd**

City of Superior, 2014. Personal communication

Cole, R. H., Frederick, R. E., Healy, R. P., and R. G. Rolan, 1984. Preliminary findings of the priority pollutant monitoring project of the nationwide urban runoff program. *J. of Water Pollution Control Federation*. **56**(7):898-908.

Davis, A. P., M. Shokouhian, and S. Ni, 2001. Loading estimates of lead, copper, cadmium, and zinc in urban runoff from specific sources. Chemosphere **44**: 997-1009.

Environment Canada and the United States Environmental Protection Agency (EC and USEPA), 1998. *Atmospheric Deposition of Toxic Substances to the Great Lakes: IADN Results through 1998*. EPA- 905-R-01-007.

EC and USEPA, 2000. *Atmospheric Deposition of Toxic Substances to the Great Lakes: IADN Results through 2000*. EPA- 905-R-04-900. http://www.msc.ec.gc.ca/IADN

EC and USEPA, 2005. *Atmospheric Deposition of Toxic Substances to the Great Lakes: IADN Results through 2005*. EPA-905-R-08-001

Ellingwood, B. and R. K. Redfield, 1984. Probability models for annual extreme water-equivalent ground snow. *Mon. Wea. Rev.* Vol. 112: 1153-1159.

Field, R., Pitt, R., Lalor M, Brown, M., Vilkelis W., and E. Phackston, 1994. Investigation of dry-weather pollutant entries into storm-drainage systems. *J. of Environ. Eng.* **120**(5):1044-1066.

Francey, M.; Duncan, H. P.; Deletic, A.; and T. D. Fletcher, 2011. Testing and sensitivity of a simple method for predicting urban pollutant loads. J. Environ. Eng. **137**:782-789.

Gatz D. (1975). Pollutant Aerosol Deposition into Southern Lake Michigan. *Water, Air, and Soil Pollution 5:* 239-251.

Gatz D., Bowersox V, and J Su (1989). Lead and Cadmium Loadings to the Great Lakes from Precipitation. *J. Great Lakes Res. 15(2):246-264*.

Gupta, 1981. *Constituents of highway runoff: Vol.. I., state-of-the-art report : final report.* Federal Highway Administration. USDOT.

Hewitt C. N. and Rashed M. B. 1992. Removal rates of selected pollutants in the runoff waters from a major rural highway. *Wat. Res*. 26(3):311-319

Hoff R., Strachan W., Sweet C., Shackleton M., Bidleman T., Bricell K., Burniston D., Cussion S., Gatz D., Harlin K., and W. Schroeder (1996). Atmospheric deposition of toxic chemicals to the Great Lakes: A review of data through 1994. *Atmospheric Environment, **30**(20): 3505–3527*

Huber, W. C., and R. E. Dickinson,1988. Storm water management model, Version 4 Part A: User's manual. EPA-600/3-88-001a, U.S. Environmental Protection Agency, Athens, Ga.

International Joint Commission (IJC). Atmospheric Loading of the Lower Great Lakes and the Great Lakes Drainage Basin. March 1977.

International Maritime Organization (IMO), 2015. *International Convention on the Control of Harmful Anti-fouling Systems on Ships*. Available: http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-the-Control-of-Harmful-Anti-fouling-Systems-on-Ships-(AFS).aspx

Klein D. (1975). Fluxes, Residence Times, and Sources of Some Elements to Lake Michigan. *Water, Air, and Soil Pollution*. **4**(1):3-8

Lankey R., Davidson C., and F. McMichael (1998). Mass Balance for Lead in the California South Coast Air Basin: *An Update. Environmental Research, Section A 78. Article No. ER983853.* Available: http://www.cmu.edu/gdi/docs/mass-balance-for-lead.pdf

Lord B. N., 1987. Nonpoint source pollution from highway stormwater runoff. *The Science of the Total Environment* **59**:437-446.

Malina, J. F., Jr., Barrett, M. E., Jackson, A, and T. Kramer, 2006. *Characterization of stormwater runoff from a bridge deck and approach highway and effects on receiving water quality*. Center for Transportation Research at the University of Texas at Austin. FHWA/TX-06/0-4543-1. Available: http://www.utexas.edu/research/ctr/pdf_reports/0_4543_1.pdf

Minnesota Department of Transportation (2012). Interstate 535 John A. Blatnik Bridge. Fact Sheet. Available: **http://www.dot.state.mn.us/d1/projects/blatnikbridge/pdf/BlatnikFactSheet.pdf**

Morquecho, R., Pitt, R., and S. E. Clark, 2005. Pollutant associations with particulates in stormwater. *Impacts of Global Climate Change. Ed. Raymond Walton. American Society of Civil Engineers.*

Mustard, M. H., Driver, N. E., Chyr, J., and B. G. Hansen, 1987. *U.S. Geological Survey urban-stormwater data base of constituent storm loads; characteristics of rainfall, runoff, and antecedent conditions; and basin characteristics.* U.S. Geological Survey, Denver, Colorado.

NOAA, 2014. Report requested in 2014 on website. National Climatic Data Center (NCDC), NSCR, 2014. Retrieved in 2014 on http://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/snow/?cid=nrcs142p2_046155

Paul F. Woods, 2001. *Concentrations and Loads of Cadmium, Lead, and Zinc Measured Near the Peak of the 1999 Snowmelt-Runoff Hydrographs for 42 Water Quality Stations, Coeur d'Alene River Basin, Idaho*. USGS. Open-File Report 00–322. Available: http://pubs.usgs.gov/of/2000/0310/report.pdf

Pitt R. and J. Voorhees, 2002. SLAMM, the Source Loading and Management Model. Published in: *Wet-Weather Flow in the Urban Watershed: Technology and Management*. Ed: Field R. and D. Sullivan, CRC Press. Boca Raton, FL.

Pitt, R., Williamson, D., Bannerman, R. T., and Clark, S 2004. *Sources of Pollutants in Urban Areas.* Available: http://dnr.wi.gov/topic/stormwater/documents/sources_urban.pdf

Pitt, R. 1985. *Characterizing and controlling urban runoff through street and sewerage cleaning*. Project Summary. USEPA. Water Engineering Research Laboratory, Cincinnati, OH 45268. EPA/600/s2-85/038. June.

Pitt, R., Maestre, A, Morquecho R., 2003. Evaluation of NPDES Phase1 Municipal Stormwater Monitoring Data. National Conference on Urban Storm Water: Enhance Programs at the Local Level. USEPA and the Chicago Botanic Garden, Chicago, IL.

Pitt, R., Maestre, A, Morquecho R., Brown, T. Swann, C, Cappiella, K and Tom Schueler, 2003. *Evaluation of NPDES Phase I Municipal Stormwater Monitoring Data.* Available on http://water.epa.gov/polwaste/nps/stormwater/upload/2003_03_26_NPS_natlstormwater03_28Pitt.pdf

Rasmussen, 1998. Long-range Atmospheric Transport of Trace Metals: the Need for Geoscience perspectives. Environmental Geology 33(2/3): 96:108.

Sanderson, M., Marchand D., and P. McQuarrie, 1985. Surface Deposition of Lead and Cadmium from the Atmosphere in the Detroit River – Lake St. Clair Region. *J. Great Lakes Res. 11(3):305-312*.

Schmidlin, T. W., 1990. A critique of the climate records of "water equivalent of snow on the ground" in the United States. J. of Applied Meteorology. Vol. 29(11):1136-1141.

Schmidlin, T. W., Wilks, D. S., McKay M., and Cember, R. P., 1995. Automated quality control procedure for the "water equivalent of snow on the ground" measurement. J. of Applied Meteorology. Vol. 34(1): 143-152.

Shulski M. and M. Seeley, 2002. *Climatological characterization of snowfall and snowdrift in Minnesota (for the design of living snow fences). Task 2 Report*. Mn/DOT Agreement No. 74708. Available: http://snowfence.umn.edu/Components/tasksummaryreports.htm

Sweet C., Weiss A. and S. Vermette, 1998. Atmospheric Deposition of Trace Metals at Three Sites Near the Great Lakes. *Water, Air, and Soil Pollution* **103:** 423–439.

Thosmson, N. R., McBean, E. A., Snodgrass W., and I. B. Monstrenko, 1997. Highway Stormwater Runoff Quality: Development of Surrogate Parameter Relationships. Water Air and Soil Pollution **94**(3-4):307-347.

USDOT, 1990a. *Pollutant loadings and impacts from highway stormwater runoff, volume I: design Procedure*. Federal Highway Administration (FHWA), Publication No. FHWA-RD-88-006.

USDOT, 1990b. *Pollutant loadings and impacts from highway stormwater runoff, volume III: analytical investigation and research report*. Federal Highway Administration (FHWA), Publication No. FHWA-RD-88-006.

USDOT, 2002. *Route Log and Finder List.* The Dwight D. Eisenhower National System of Interstate and Defense Highways. Retrieved on Aug. 20, 2015: http://www.fhwa.dot.gov/reports/routefinder/index.htm

USDOT, 2014. *National Transportation Statistics*. Available: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/index.html

USEPA, 1972. *Water pollution aspects of street surface contaminants.* Office of Research and Monitoring, EPA-R2-72-081.Washington, D. C., 20460.

USEPA,1973. *EPA Requires Phase-Out of Lead in All Grades of Gasoline*

USEPA,1981. National Air Quality and Emissions Trends Report. U.S. Environmental Protection Agency, Washington, DC, *EPA/450/4-83-011*

USEPA, 1983. *Results of the nationwide urban runoff program, volume 1-final report*. National Technical Information Service (NTIS). Publication No. PB84-185552. Washington, D. C., 20460

USEPA, 1985a. *EPA Sets New Limits on Lead in Gasoline*, EPA Press release. Available:http://www.lb7.uscourts.gov/documents/INND/207CV56-2.pdf

USEPA,1985b. National Air Quality and Emissions Trends Report. U.S. Environmental Protection Agency, Washington, DC, *EPA/450/4-87-001*

USEPA, 1995. *Storm water discharges potentially addressed by Phase II of the national pollutant discharge elimination system storm water program.* EPA 833-K-94-002.

USEPA,1996. *EPA Takes Final Step in Phaseout of Leaded Gasoline,* EPA Press

USEPA, 2000. Deposition of Air Pollutants to the Great Waters Third Report to Congress. Environmental Protection Agency Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA-453/R-00-005

USEPA, 2013. Integrated Science Assessment for Lead – Final Report. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-10/075F, 2013

USEPA, retrieved in 2014. Available:: http://www.epa.gov/airtrends/lead.html

USGS, 1995. *Evaluation of nonpoint –source contamination, Wisconsin: selected streamwater-quality data, land-use and best management practices inventory, and quality assurance and quality control, water year 1993*. Prepared in cooperation with the Wisconsin DNR. Open-file report 94-707.

USGS, 2015. *SLAMM Source Loading and Management Model Parameter and Starndard Land Use Files for Wisconsin*. Available: http://wi.water.usgs.gov/slamm/ and http://wi.water.usgs.gov/slamm/slamm_parameter_descriptions.htm.

Walker, J. F. 1993. *Techniques for detecting effects of urban and rural land-use practices on stream-water chemistry in selected watersheds in Texas, Minnesota, and Illinois.* USGS, Open-file report 93-130. Prepared in cooperation with the Wisconsin Department of Natural Resources

WDNR and MN, 1961. Making of the Opening of the Duluth-Superior High Bridge. Dedication program.

WDNR and MPCA,1992. *The St. Louis River System Remedial Action Plan*. Available: http://dnr.wi.gov/topic/greatlakes/documents/SLRRAP1992.pdf

WDNR, 1983. *Evaluation of urban nonpoint source pollution management in Milwauke County, Wisconsin*. Volume 1: urban stormwater characteristics, sources and pollutant management by street sweeping. Publication No. PB 84-114164.
WDNR, 1992. *Sources of pollutants in Wisconsin Stormwater*. April. 23.
WDNR, 2015a. Storm Water Runoff Permits. Available: http://dnr.wi.gov/topic/stormwater/
WDNR, 2015b. *Wisconsin Department of Natural Resources Wisconsin Air Quality Trends. Publication Number AM-526-2015*

Winchester J. W. and G. D. Nifong. 1971. Water Pollution in Lake Michigan by Trace Elements from Pollution Aerosol Fallout. *Wat., Air, Soil. Pollut.* 1:50-64
Wisconsin Department of Transportation,

WDOT websites:
http://wisconsindot.gov/Documents/travel/road/hwy-maps/freeways.pdf
http://www.wisconsinhighways.org/listings/WiscHwys400-894.html

APPENDIX A NAUTICAL CHARTS

(Available: http://www.nauticalcharts.noaa.gov/csdl/ctp/abstract.htm)

APPENDIX A NAUTICAL CHARTS

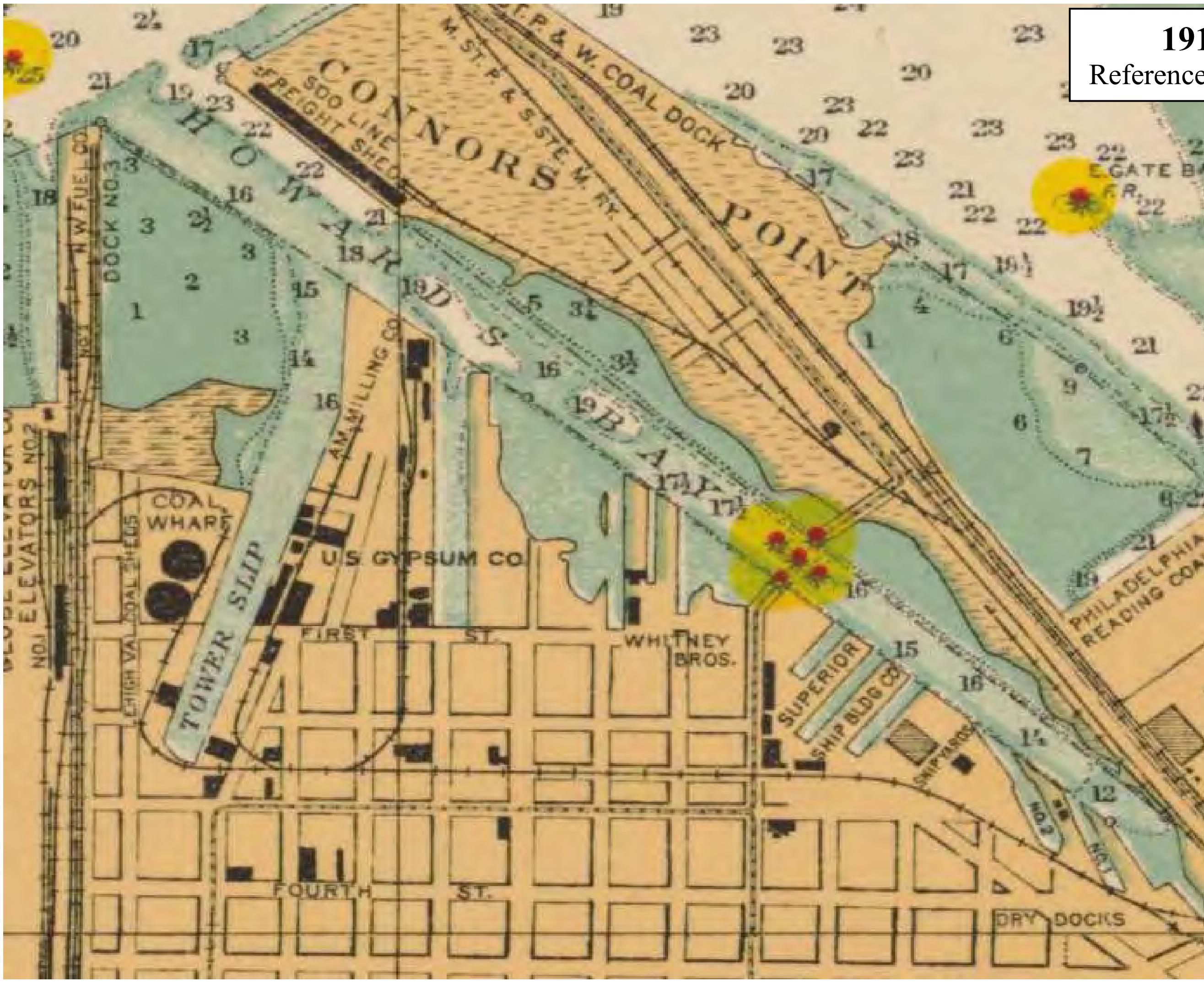


Fig. A-1 Nautical Charts for the Howards Bay project area 1915 (NOAA(a): http://www.nauticalcharts.noaa.gov/csdl/ctp/abstract.htm)

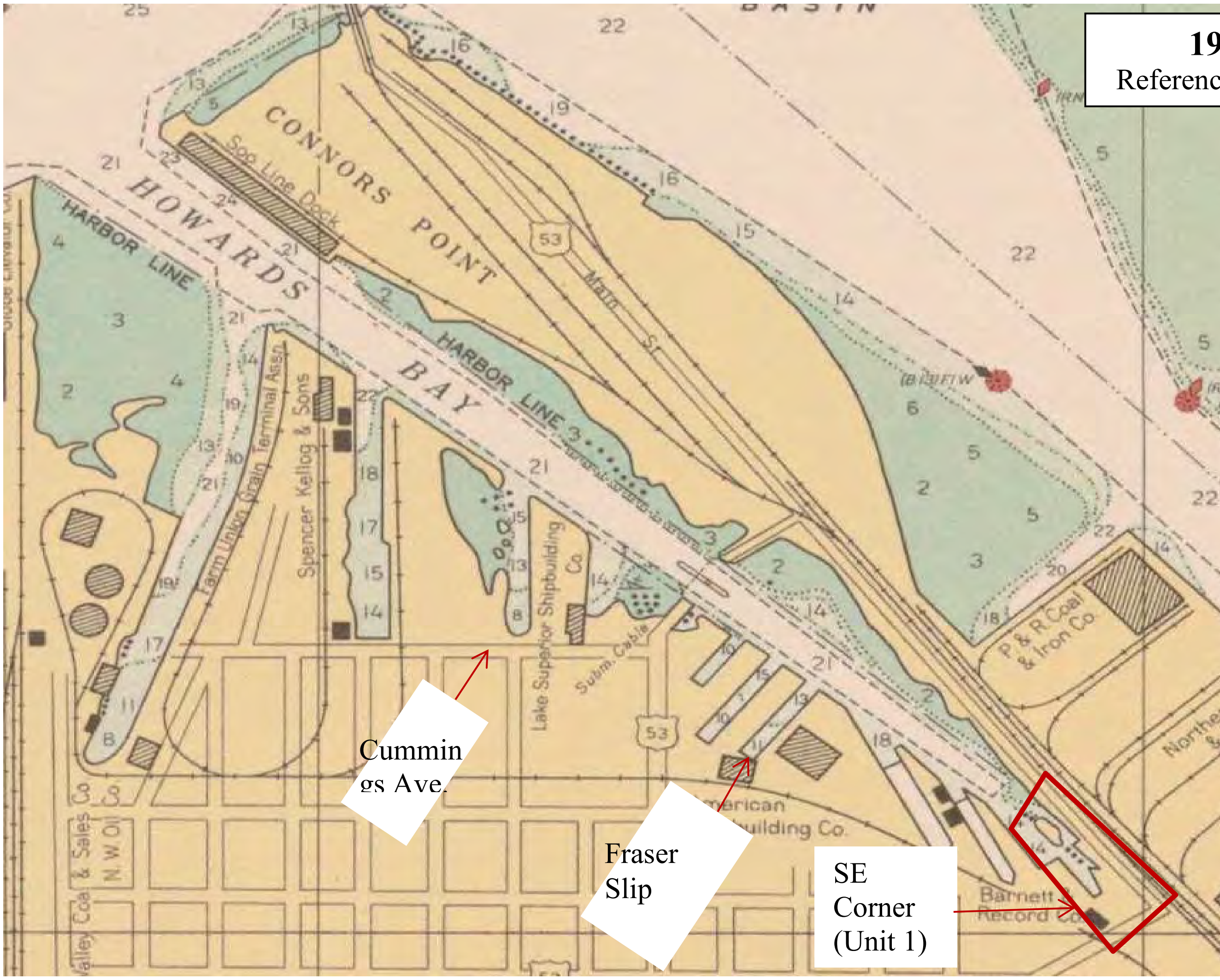


Fig. A-2 Nautical Charts for the Howards Bay project area-1943

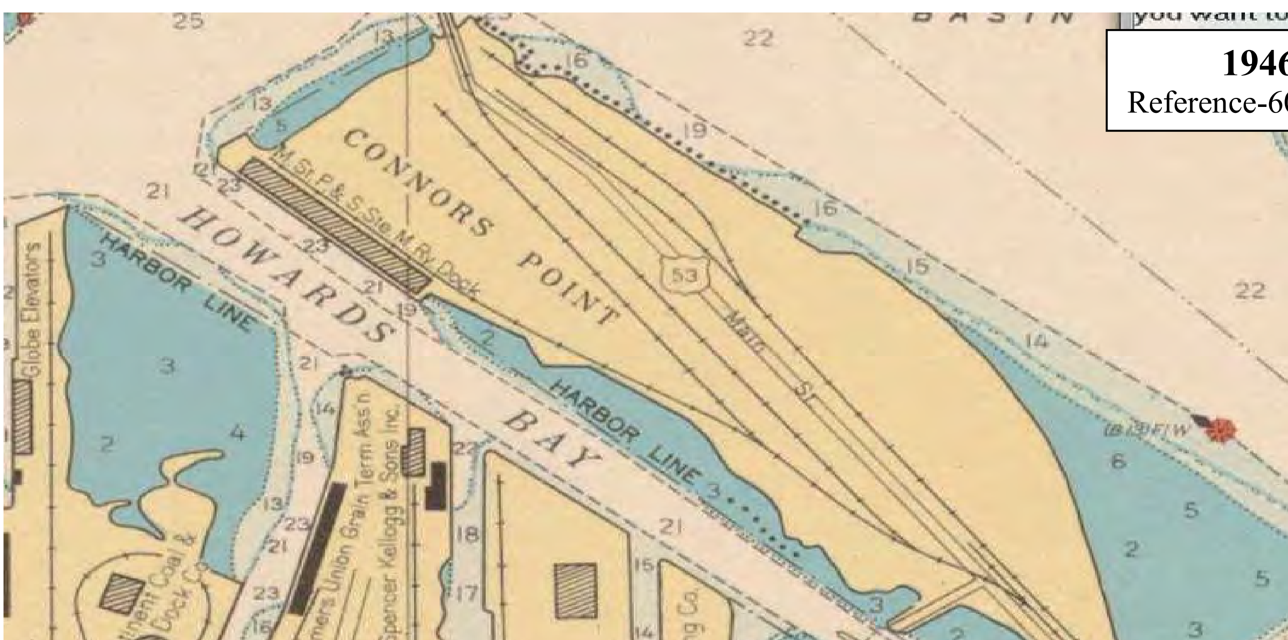


Fig. A-3 Nautical Charts for the Howards Bay project area-1946

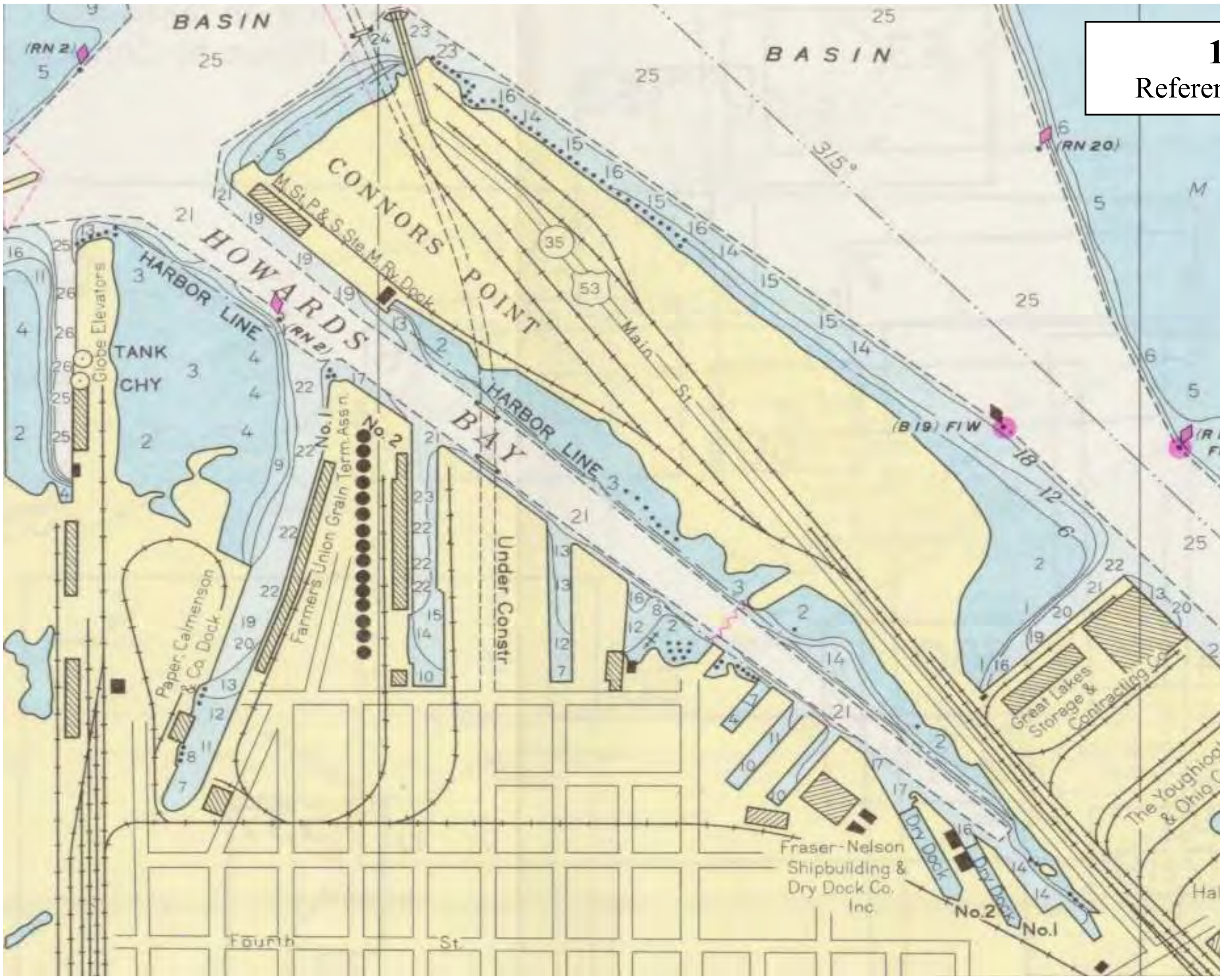


Fig. A-4 Nautical Charts for the Howards Bay project area-1961

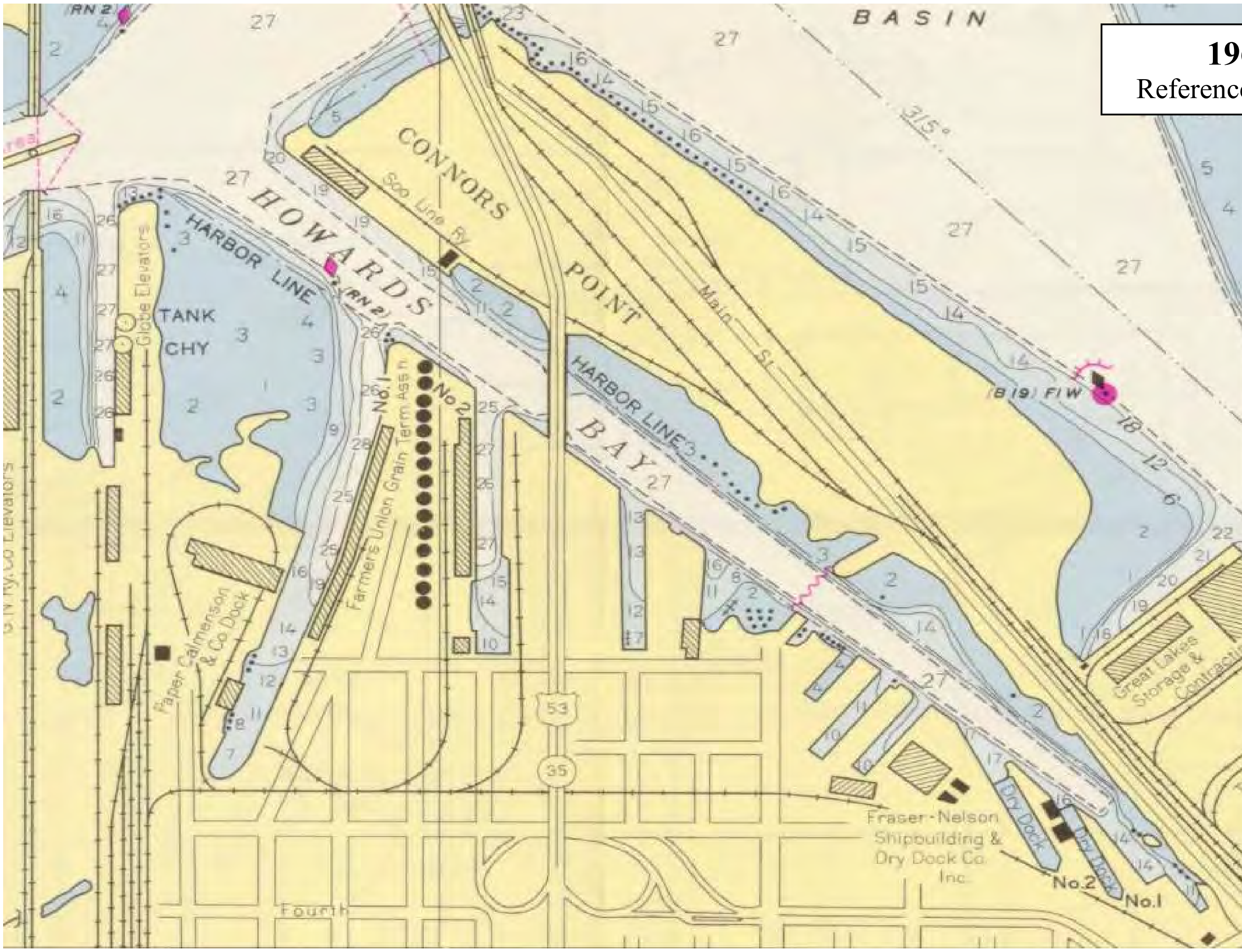


Fig. A-5 Nautical Charts for the Howards Bay project area-1964

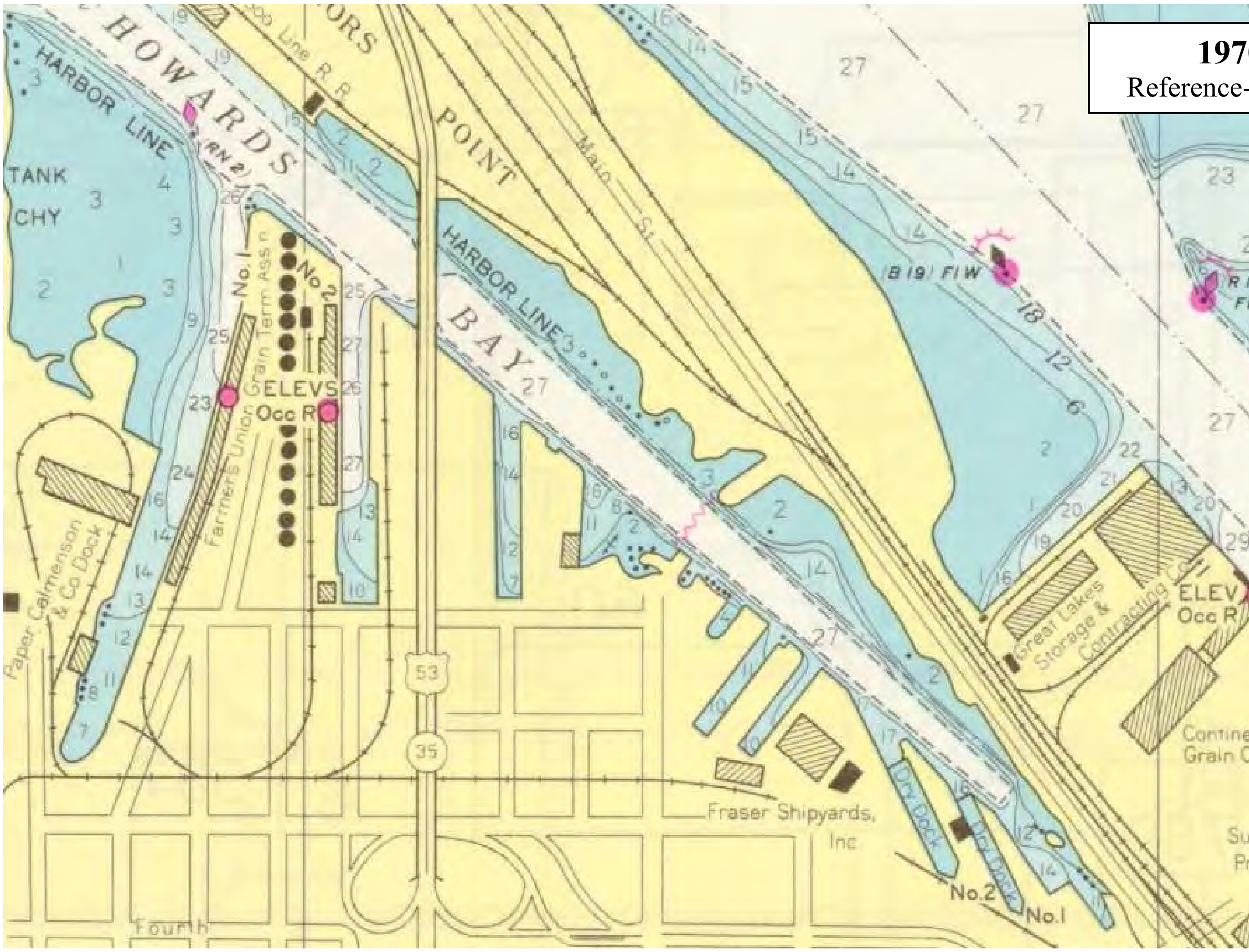


Fig. A-6 Nautical Charts for the Howards Bay project area-1970

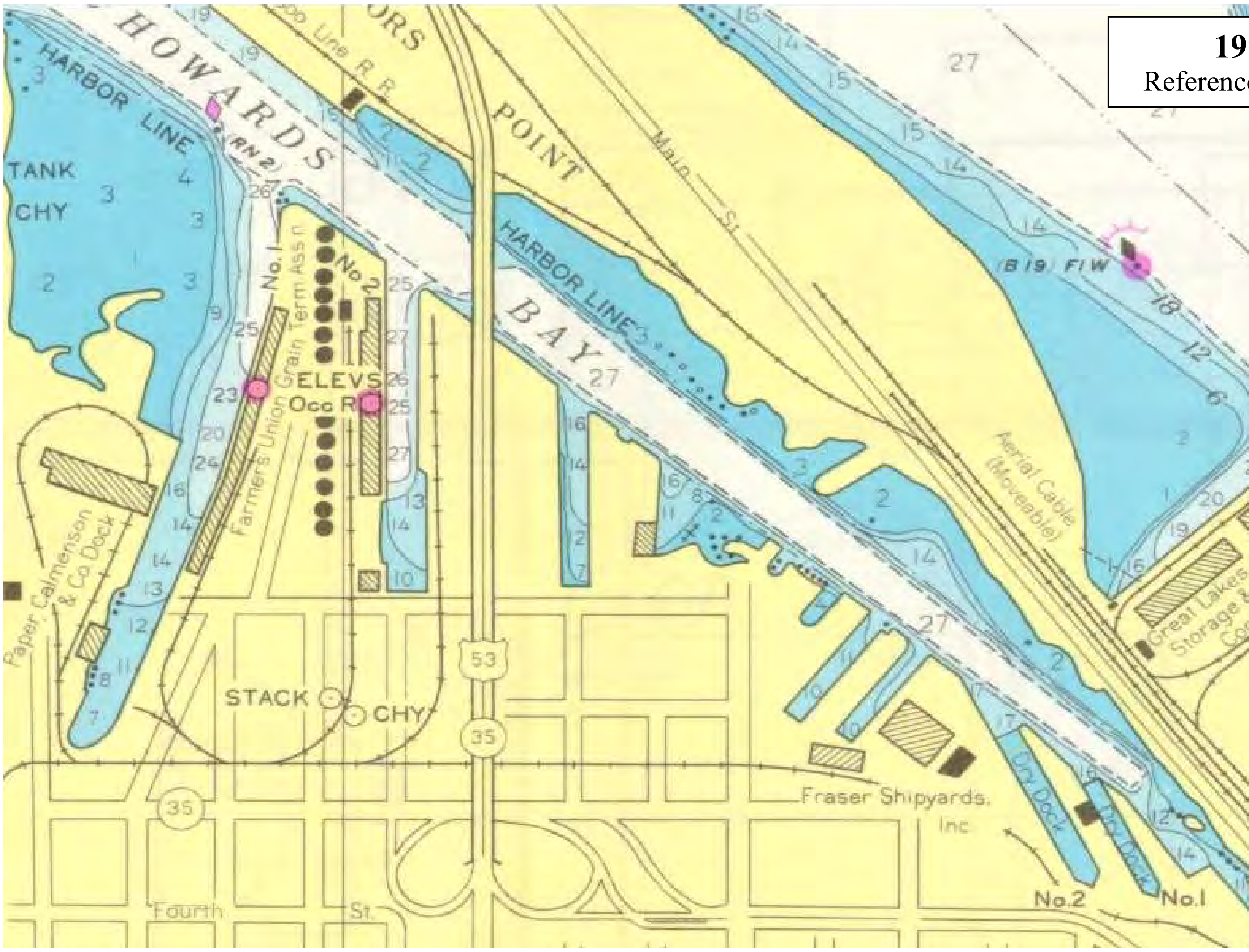


Fig. A-7 Nautical Charts for the Howards Bay project area-1973

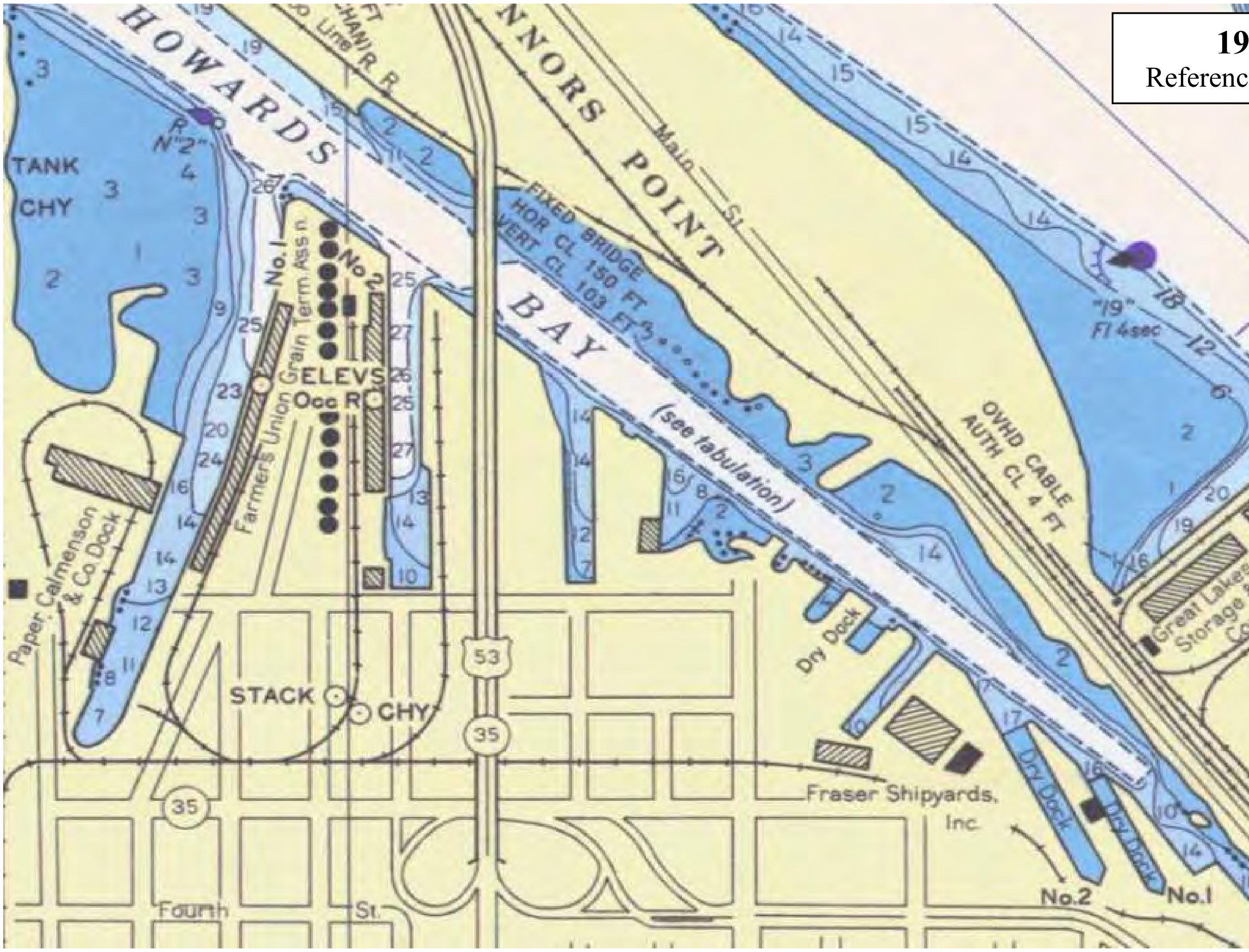


Fig. A-8 Nautical Charts for the Howards Bay project area-1976

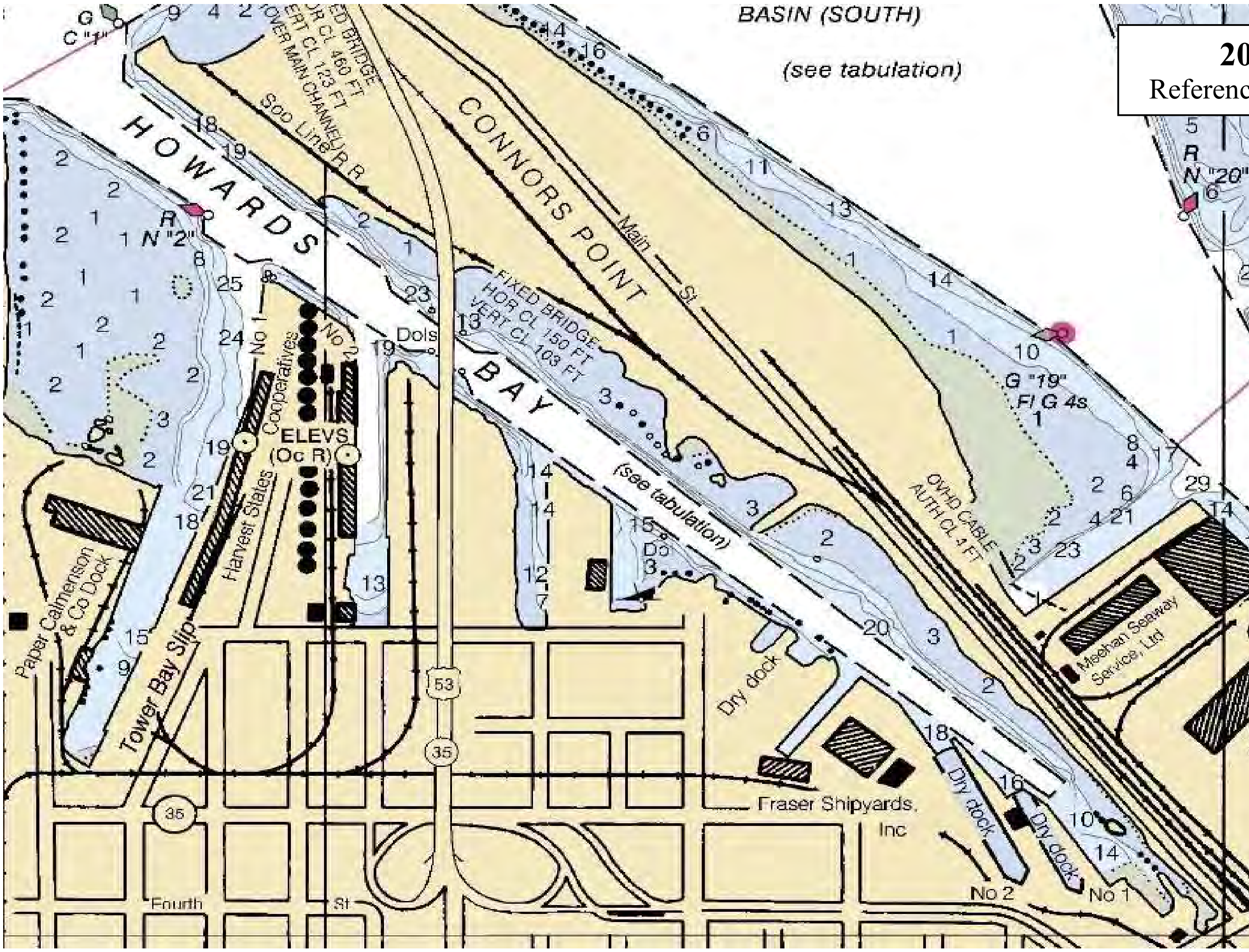


Fig. A-9 Nautical Charts for the Howards Bay project area-2007

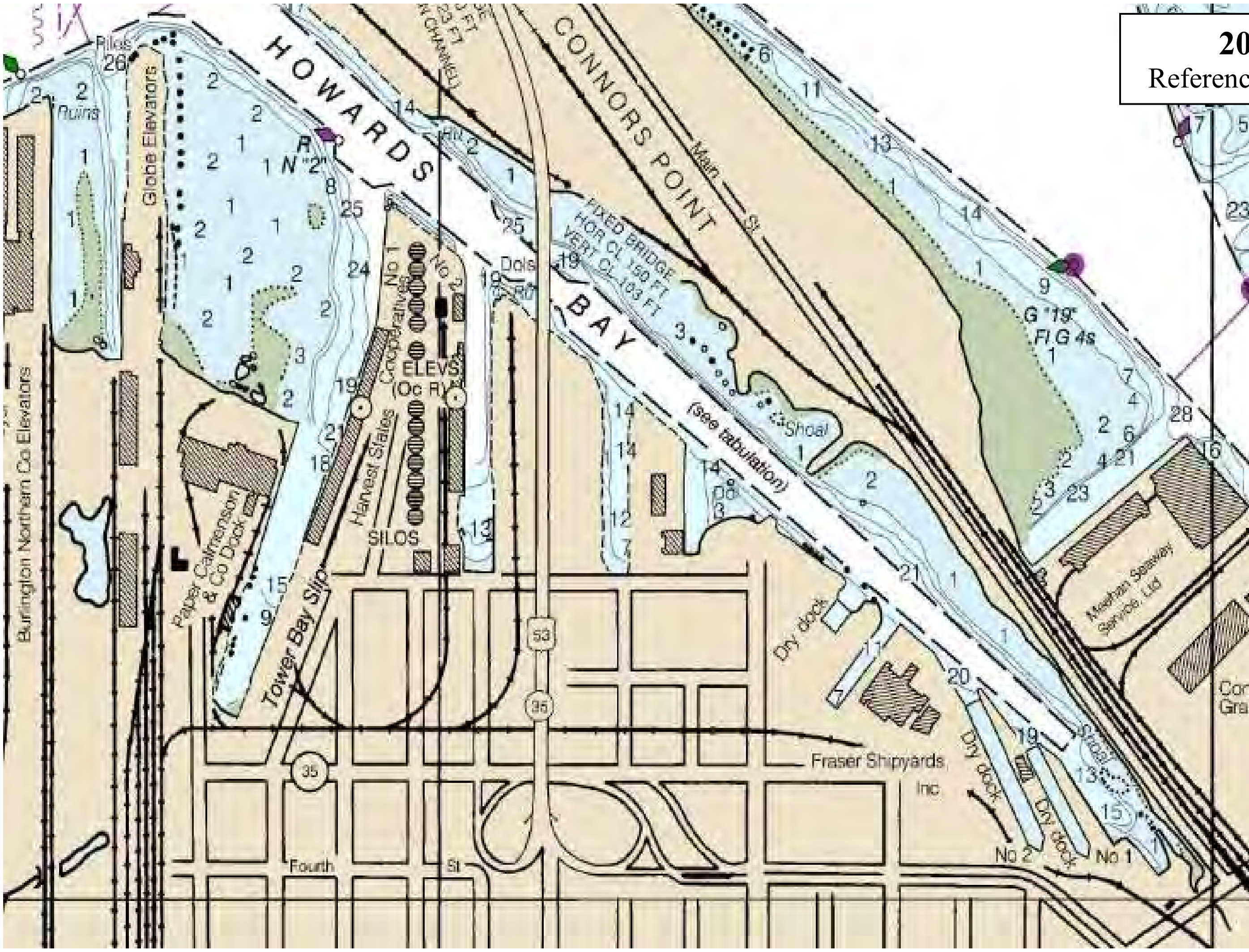


Fig. A-10 Nautical Charts for the Howards Bay project area-2014

APPENDIX B ANNUAL REPORT UNDER MS4 GENERAL PERMIT, CITY OF SUPERIOR, MARCH, 2015

State of Wisconsin
Department of Natural Resources
dnr.wi.gov

Annual Report under MS4 General Permit No. WI-S050075-2

Form 3400-195 (R 10/14)

Due by March 31, 2015

Notice: Pursuant to s. NR 216.07(8), Wis. Adm. Code, an owner or operator of a Municipal Separate Storm Sewer System (MS4) is required to submit an annual report to the Department of Natural Resources (DNR) by March 31 of each year to report on activities for the previous calendar year. This form is being provided by the DNR for the user's convenience. Personal information collected will be used for administrative purposes and may be provided to the extent required by Wisconsin's Open Records Law [ss. 19.31-19.39, Wis. Stats.].

This form is for reporting on activities undertaken in calendar year 2014.

Instructions: Complete each section of the form that follows. If additional space is needed to respond to a question, attach additional pages. Provide descriptions that explain the program actions taken to comply with the general permit. Complete and submit the annual report by March 31, 2015, to the appropriate address indicated on the last page of this form.

SECTION I. Municipal Information

Name of Municipality	Facility ID No. (FIN)
City of Superior	31044

Mailing Address	City	State	ZIP Code
51 East First Street	Superior	WI	54880

County(s) in which Municipality is located	Municipality Type: (select one)
Douglas	○ County ◉ City ○ Village ○ Town ○ Other (specify)

SECTION II. Municipal Contact Information

Name of Municipal Contact Person	Title
Diane Nelson	Stormwater and Administrative Manager

Mailing Address (if different from above)	City	State	ZIP Code
51 E 1st Street	Superior	WI	54880

Email	Phone Number (include area code)	Fax Number (include area code)
nelsond@ci.superior.wi.us	(715) 394-0392	(715) 394-0406

SECTION III. Certification

I hereby certify that I am an authorized representative of the municipality covered under MS4 General Permit No. WI-S050075-2 for which this annual report is being submitted and that the information contained in this document and all attachments were gathered and prepared under my direction or supervision. Based on my inquiry of the person or persons under my direction or supervision involved in the preparation of this document, to the best of my knowledge, the information is true, accurate, and complete. I further certify that the municipality's governing body or delegated representatives have reviewed or been apprised of the contents of this annual report. I understand that Wisconsin law provides severe penalties for submitting false information.

Authorized Representative Printed Name	Authorized Representative Title
Jeff Goetzman	Director, Public Works
Signature of Authorized Representative	Date

Email	Phone Number (include area code)	Fax Number (include area code)
goetzmanj@ci.superior.wi.us	(715) 395-7334	(715) 395-7346

SECTION IV. General Information

a. Describe what efforts the municipality has undertaken to invite the municipal governing body, interest groups, and the general public to review and comment on the annual report.

The annual report is submitted to the City Council for review and comments one week before the last council meeting in March. Storm water staff are available at the council meeting to answer questions and provide any additional information, etc.

Advertisements were placed in two local papers inviting the general public to attend a meeting at the public library to comment on the annual report. The annual report is available on our web page. It can also be requested in hard copy.

b. Describe how elected and municipal officials and appropriate staff have been kept apprised of the municipal storm water discharge permit and its requirements.

Storm water Utility staff attend council, finance, public works, and other committee meetings to provide information and updates on the activities of the Stormwater Utility.

SECTION IV. General Information (continued)

c. Has the municipality prepared its own municipal-wide storm water management plan? (●) Yes ( ) No

If yes, title and date of storm water management plan:

City of Superior Stormwater Management Plan 4/10/2012

d. Has the municipality entered into a written agreement with another municipality or a contract with another entity to perform one or more of the conditions as provided under section 2.10 of the general permit? ( ) Yes (●) No

If yes, describe these cooperative efforts:

e. Does the municipality have an internet website? (●) Yes ( ) No

If yes, provide web address:
http://www.ci.superior.wi.us

If the municipality has an internet website, is there current information about or links provided to the MS4 general permit and/or the municipality's storm water management program? (●) Yes ( ) No

If yes, provide web address:
http://www.ci.superior.wi.us/stormwater

SECTION V. Permit Conditions

a. Minimum Control Measures: For each of the permit conditions listed below, provide a description of the implementation of each program element, the status of meeting measurable goals, and compliance with permit schedule in section 2.11 of the MS4 general permit. Provide an evaluation of program compliance with the general permit, the appropriateness of identified best management practices, and progress towards achieving identified measurable goals. Be specific in describing the actions that have been taken during the reporting year to implement each permit condition and whether measurable goals have been met, including any data collected to document a measurable goal. Also, explain the reasons for any variations from the compliance schedule in the MS4 general permit.

- Public Education and Outreach

  Public Education Involvement and Relations (PEIR) staff met our measurable goals of attending 12 local events, distributing a semi-annual newsletter, inviting all 5th graders to tour the Superior Wastewater Treatment Plant, attending monthly meetings of the Regional Stormwater Protection Team, provide stormwater information through webpages, and develop in-house brochures and flyers on relevant topics.

  PEIR staff attended and coordinated numerous events in 2014 to provide educational materials on relevant topics. Noted events include an educational fair coordinated by PEIR staff for Bryant and Cooper 5th graders; tours of the wastewater treatment plant to all 5th grade students in the spring; PEIR staff held a composting workshop and soil sampling class; a Storm drain art contest and exhibit was held to the public in the summer; and a bus tour of local stormwater management practices. In addition, PEIR staff also organized a Water video nights, Toilet Day, weed walk, Protect Our Waters Fun Fair, and Let's Talk Recycling, with presentations by local experts. Educational displays at 3 locations (Government Center, Mall, Business Center) are continuously rotated with relevant water-related topics. PEIR staff created educational displays and brochures/flyers for these events. A full list of PEIR activities is included in the attached 2014 PEIR Activity Log.

  The PEIR staff used a variety of media to educate the community. Many in-house brochures (topics include: waste disposal guide, what not to flush, pet waste, mercury) were developed and distributed at local events. The stormwater newsletter, "A Drop of News" was mailed to all property owners in the City of Superior in January and July with stormwater utility bills. A 10-second public service announcement on slowing down stormwater runoff was developed and ran on a local TV station. PEIR staff also maintains the City Environmental Services Division website and regularly posts on several social media websites.

SECTION V. Permit Conditions (continued)

- Public Involvement and Participation

Many of the City's methods for involving the public are used as part of our public outreach efforts. These methods include public notices, public meetings, document distribution, surveys, and volunteer opportunities. City projects, activities, and local events also give citizens an opportunity to provide input on water quality issues, give feedback on projects and allow the public the opportunity to talk to PEIR staff about their individual concerns. This informal exchange provides invaluable information that is used to evaluate and further improve the PEIR program.

The City offered a variety of opportunities for public involvement and participation. The Annual Stormwater Public Information Meeting was held in March to give the public the opportunity to view the report and comment. Four surveys were given in 2014 at different outreach events. A survey of water quality was given at the February Film Night; stormwater importance survey was done at the Fish & Game Show and Tower Ave Re-opening; and a composting survey was given at the composting workshop. PEIR staff also offered 2 public contests to engage the community: (1) Poetry contest on why water is important and (2) A storm drain art contest for local artists to develop unique drain art. The public was also invited to participate in the stormwater program by stenciling storm drains - a school club, Boys & Girls group, and public volunteers stenciled anti-pollution messages near drains. The City partnered with UWS to hold a rain barrel and compost sale. The sale gave citizens the opportunity to reduce stormwater runoff from their properties and to reuse yard waste onsite. An ongoing effort to involve the public in stormwater activities is the stormwater (illicit discharge) hotline.

- Illicit Discharge Detection and Elimination

The City has met two measurable goals: (1) implementing an Illicit Discharge Ordinance since 2010 and (2) performing initial field screening of all 19 major outfalls. The on-going best management practice [bmp] is continual field screening of outfalls (annual screening of 50% major and 20% minor outfalls).

The City successfully met our measurable goal of field screening 50% of the major outfalls and 20% of minor outfalls (9 and 18, respectively) for illicit discharge in 2014. Screening occurred 48 hours after the last runoff-producing precipitation event and included visual observation of color, odor, oil sheen/surface scum, outfall damage, visible flow, and other relevant observations regarding the potential presence of non-stormwater discharges. Flow was observed for 8 major and 3 minor outfalls and analyzed to determine potential illicit discharge source.

All outfalls screened in 2014 were successfully located. Other than observed flow, none of the major outfalls screened had any other visible issues. There were a few issues with the screened minor outfalls: 2 of the minor ones were mislabeled as outfalls; 2 minor outfalls were buried under ground/sediment (likely due to the 2012 flood); 1 minor outfall was privately extended; and 1 minor outfall had recently been combined with a nearby major outfall. Maintenance and cleaning requests were sent at the end of the field season to address these issues. A request to update storm sewer maps was also sent.

A summary of the 2014 Field Screening can be found in the Illicit Discharge Field Screening Activity tables.

Illicit Discharge Response

During 2014 field screening, the 11 outfalls (8 major, 3 minor) that were identified as having potential illicit discharge concerns were sampled and analyzed for potential flow sources. Stormwater flow was analyzed for detergents, potassium, fluoride, and ammonia. Using the CWP IDDE Manual's Flow Chart, all flows were determined to be from natural sources.

Details are attached.

SECTION V. Permit Conditions (continued)

- Construction Site Pollutant Control

  The total number of erosion control permits that were issued and approved by the City of Superior for the year 2014 was 50 permits. Among those, 12 were City of Superior projects and 38 that were private contractors and land owners. The non-City projects were divided into two main categories: Commercial buildings and residential projects. There were 26 residential project permits issued in the year of 2014 versus 12 permits that covered commercial buildings. Chart summarizing the permit breakdown is attached.

  The City of City of Superior coordinates with project owners and managers the dates of field inspection prior to issuing erosion control permits. Field inspections aim at enforcing the original erosion control practices that were approved by the City at the time of application review. If field conditions changed after permit review, the City always finds the best practical solution to accommodate for the change and maintain a good control on preventing any possible erosion.

  The vast majority of the projects that were executed within the City limits go as planned. If field inspections reveal any alteration or potential to soil erosion, the City always alerts the project owner immediately to gain control on situation and address the concern immediately. This is being implemented by either: phone or email and a formal letter whichever is faster. If in certain circumstances, there was no cooperation from the project manager or owner, the City takes this a step further and issue a citation. The City of Superior has been successful in containing the action required in the first phase with additional field inspections as required.

- Post-Construction Storm Water Management

  During 2014, 11 Post-Construction Stormwater Management (PCSM) permits were issued. All 11 permits had pre-construction review(s) prior to permit application submission. On a couple of the projects the DNR was contacted for questions/suggestions on planning to ensure concurrence with the designs. In the 11 projects there was a mix of BMP types that were implemented including; wet and dry detention ponds, biofiltration, filtration trench, grass swales, and hydrodynamic devices.

  The "City of Superior Building Construction Policies and Procedures" document spells out the specific requirements for the city PCSM permit. It uses the NR 151 code as a base and includes modifications to parts of NR 151.12 to better suit the cities expectations. At present we are working on updating our Ordinances to better match the most recent Wisconsin DNR Ordinances, making sure everything is either covered in our policy documents or in the ordinance.

- Pollution Prevention

  A rigorous street sweeping was conducted from April through November 2014 with 2358 tons of sweepings collected and brought to the Superior Municipal Landfill.

  Salt and other deicers are limited to applications necessary to maintain public safety. The road sand application is calibrated to the best of the city's abilities. The sander is manually turned off and on with the operator's discretion to only apply sand in areas that would need it.

  The City of Superior conducts a brush cleanup in late April through May covering all neighborhoods. This enables less organic material from making its way to interfere with storm drains. City staff attended a Turf Grass Maintenance with Reduced Environmental Impacts training held April 3, 2014. Relevant municipal employees were invited and encouraged to attend. The workshop was organized through the Regional Stormwater Protection Team. The city is a member of the RSPT and regularly attends monthly meetings to share information on stormwater pollution prevention. The city also attended a Winter Parking Lot and Sidewalk Maintenance Workshop on October 28 held by RSPT.

  Environmental Services delivered the Excal Training "Raincheck Stormwater Pollution Prevention" on April 21, 22, May 1, June 10, 11, and 12. Municipal employees, including Parks & Recreation staff, Fire Department, Street Maintenance, Inspections, Collections, and Environmental Services Division attended the training included a PowerPoint, video, quiz, and activity on hypothetical scenarios "What would they do." Departments were given magnets and flyers with the Illicit Discharge Hotline phone number. The presentation included viewing maps of city storm drains.

  There is a composting site at the City Landfill. A collection of yard waste and brush were held in the spring and fall. This annual event is free and open to all residents. Grass clippings can be brought to the landfill for free. Garden debris is either brought over to WLSSD to compost or used as fill.

SECTION V. Permit Conditions (continued)

b. Winter Road Management Activities (Optional reporting for 2014):

Provide the name, title, and phone number for the individual(s) with overall responsibility for winter roadway maintenance.

Nathan Johnstad, Street Superintendent, 715-394-0244

Describe the types of products used for winter road management (e.g. deicing, pre-wetting, salting, etc.).

The products used by the City of Superior include Salt, Washed sand, and Magnesium Chloride brine mix

Describe the type of equipment used to apply the products.

The City of Superior uses Monroe sander Body with saddle tanks for Mag Chloride pre wetting Salt sand mixture on spinner

Report the amount of product used per month.

Variable depending on snow fall. Annual report for 2015 available in the spring for first half of year.

Report the snow disposal locations, if snow is hauled away.

Snow disposal locations Morterelli Drive by UWS campus, East end snow dump, Stinson and E 14th St., and Itasca mud dump on Itasca Drive, and 50th Ave E

Describe any anti-icing, equipment calibration, and salt reduction strategies considered.

Each sander is calibrated to 200# per lane mile in the beginning of winter. Manuel adjustments only per operator

Describe any other additional measurable data or information that the permittee used to evaluate its winter road management activities.

No additional measurable data at this time.

c. Municipal facility(s) (Optional reporting for 2014):

Provide an inventory of municipally owned or operated structural storm water management facility(s), include: Location of each facility and contact information for the individual(s) with overall responsibility for each facility.

See attached inventory

Describe the housekeeping activities and best management practices installed to reduce or eliminate storm water contamination.

Discuss recommendations for improvements to current storm water management practices at the facility(s) and a timeline for installation and/or implementation of these recommendations.

Describe the municipal facility(s) employee training on storm water pollution prevention provided.

Stormwater Pollution Prevention training was presented to municipal employees. The trainings included a video showing, PowerPoint, and quiz. The content was general for pollution prevention and also contained specific information for the city including number of storm drains, maps of drains, and maps of nearby rivers where the outfalls are. In 2014 trainings were given to the fire department crew and to the Street Maintenance and Parks crew and the wastewater treatment and city inspection staff. 84 people attended the 6 trainings held in April, May and June.

Describe the spill prevention and response procedures in place at the municipal facility(s).

Spill prevention training was included within the pollution prevention trainings. Scenario cards were created to involve the audience and have the attendees share 'what they would do.' Emphasis was made on not using a hose to

SECTION V. Permit Conditions (continued)

clean a spill and rather to use absorbent material and then sweep it up or use absorbent pads.

d. Storm Water Quality Management: Has the municipality completed a pollutant-loading analysis to assess compliance with the 20% TSS reduction developed urban area performance standard? (●) Yes ( ) No

If yes, provide the following: Model used WinSLAM Version 9.4 Reduction (%) 43.29

If no, include a description of any actions the municipality has undertaken during 2014 to help achieve the 20% standard.

Has the municipality completed an evaluation of all municipal owned or operated structural flood control facilities to determine the feasibility of retrofitting to increase TSS removal? ( ) Yes (●) No

If yes, describe:

e. Best Management Practices Maintenance: Does the municipality have a maintenance program for installed storm water best management practices? (●) Yes ( ) No

If yes, describe the maintenance program and any maintenance activities that have occurred for best management practices in 2014. If available, attach any additional information on the maintenance program.

The City of Superior's program to address stormwater system maintenance and best management practices includes several components such as:

1. City owned stormwater BMP grit chambers are inspected and cleaned semi-annually. Accumulated debris is removed and landfilled.
2. A storm sewer televising contract was bid and awarded in 2014. Total contract footage to be televised is 29,836 feet, of which 12,582 feet was completed in 2014. Work on the contact continues in 2015. The City anticipates the award of a new contract for storm sewer televising in 2015.
3. Maintenance repairs were performed to 135 storm sewer structures.
4. Storm sewer cleaning was performed on 3,500 feet of storm sewer in 2014.
5. Smoke testing was performed on 16,289 feet of sanitary interceptor sewer in 2014. Smoke testing verifies no cross-connection between the sanitary and storm sewer systems.
6. Substantial repair and rehabilitation work was completed on the K-Street storm sewer. The storm sewer is a 2500 foot long and 10 foot diameter brick sewer built in the 1890's and is terminus for the Faxon Creek Watershed. Through a combination of piping replacement, shotcrete repair, and utility line crossing removal, capacity through the storm sewer has been significantly increased and the sewer structurally stabilized.
7. Repairs as indicated by outfall inspections.

f. Storm Sewer System Map: Describe any changes or updates to the storm sewer system map made in the reporting year. Provide an updated map if any changes occurred during the reporting year.

-For the reporting here we had 37 WPDES industrial stormwater permit holders, 36 of which are the same as the previous year. One of the 37 is a new addition.
During the previous year there were 74 active SW and WW permits in the area.
Current maps are attached.

SECTION VI. Fiscal Analysis

a. Provide a fiscal analysis that includes the annual expenditures for 2014, and the budget for 2014 and 2015. A table to document fiscal information is provided on page 10.

The Stormwater Utility charges $5.90 per ERU or 2933 sq. ft. of impervious area. We again switched billing software this year, we are now using MuniBilling starting in Jan 2015. We offer credits to waterfront businesses and companies that install a wet or dry detention pond, underground storage or a wetland basin.

b. What financing/fiscal strategy has the municipality implemented to finance the requirements of the general permit?

☒ Storm water utility ☐ General fund ☐ Other

c. Are adequate revenues being generated to implement your storm water management program to meet the permit requirements? (●) Yes ( ) No

SECTION VI. Fiscal Analysis (continued)

Please provide a brief summary of your financing/fiscal strategy and any additional information that will assist the Department in understanding how storm water management funds are being generated to implement and administer your storm water management program.

A Stormwater Utility was formed to provide revenue for storm water management within the City. We have a GIS system for billing that is based on impervious area and use a software called MuniBilling for invoicing. Single family customers pay the minimum charge of $5.90/month.
Non-single family customers are charged based on the amount of impervious area they have. They are charged $5.90/ ERU (1 ERU = 2933 sq ft) each month, with bills sent out every 3 months (starting in 2015). A credit system is in place for non-single family customers whose property is draining directly to waters of the state or who have approved BMPs providing treatment or flow attenuation. Currently 46 customers are receiving credit.

SECTION VII. Inspections and Enforcement Actions

Note: If an ordinance listed below has previously been submitted and has not been amended since that time, a copy does not need to be submitted again. If the ordinance was previously submitted, indicate such in the space provided.

a. As of the date of this annual report, has the municipality updated or revised its construction site pollutant control ordinance in accordance with subsection 2.4.1 of the general permit? ○ Yes ◉ No If yes, attach copy or provide web link to ordinance:

b. As of the date of this annual report, has the municipality updated or revised its post-construction storm water management ordinance in accordance with subsection 2.5.1 of the general permit? ○ Yes ◉ No

If yes, attach copy or provide web link to ordinance:

c. As of the date of this annual report, has the municipality updated or revised its illicit discharge detection and elimination ordinance in accordance with subsection 2.3.1 of the general permit? ○ Yes ◉ No If yes, attach copy or provide web link to ordinance:

d. As of the date of this annual report, has the municipality adopted any other ordinances it has deemed necessary to implement a program under the general permit (e.g., pet waste ordinance, leaf management/yard waste ordinance, parking restrictions for street cleaning, etc.)? ○ Yes ◉ No If yes, attach copy or provide web link to ordinance:

e. Provide a summary of available information on the number and nature of inspections and enforcement actions conducted during the reporting period to ensure compliance with the ordinances described in a. to d. above.

IDDE: There were 8 reports of Illicit Discharge in 2014. After inspection, only 3 required notification of violation of Illicit Discharge letters (Resident dumping auto fluids into sewer drain; homeowner keeping open containers of oil; welding wash water draining into storm sewers). All issues were resolved and no further enforcement was necessary.
PCSM: Inspections have been made for all sites that have applied for and acquired PCSM permits. Contractors are provided with milestones sheet that indicates when they need to contact the City for inspections. Inspection milestone is triggered whenever a SW BMP is being installed and a city employee needs to be present to document. Documentation has been done using pictures, plans, and GPS points.
In 2014 there were 13 PCSM permits issued in the City of Superior. Of the 13 permits issued there was one enforcement action taken with owner of Spartan Circle Development; located South of North 28th Street & East of Weeks Ave for hiring sub-contractors who have received repeated notices for failure to maintain proper control of soils being transported on/ off the site with respect to erosion control.
EROSION: Erosion inspections are conducted by Building Inspection staff every time they are on an active site. One NOV was issued, however it was later rescinded by City Administration. Minor violations were resolved with oral notifications.

SECTION VIII. Water Quality Concerns

a. Does any part of the MS4 discharge to an outstanding resource water (ORW) or exceptional resource water (ERW) listed under s. NR 102.10 or 102.11, Wis. Adm. Code? (A list of ORWs and ERWs may be found on the Department's Internet site at: http://dnr.wi.gov/topic/surfacewater/orwerw.html) ○ Yes ◉ No If yes, list:

SECTION VIII. Water Quality Concerns (continued)

b. Does any part of the MS4 discharge to an impaired waterbody listed in accordance with section 303(d)(1) of the federal Clean Water Act, 33 USC § 1313(d)(1)(C)? (A list of the most current Wisconsin impaired waterbodies may be found on the Department's Internet site at: http://dnr.wi.gov/water/impairedsearch.aspx?status=303d) ◉ Yes ○ No If yes, complete the following:

- Impaired waterbody to which the MS4 discharges:

  Lake Superior (Barker's Island Inner Beach, Middle River Beach, Wisconsin Point Beach #2, and Lake Superior), Nemadji River, Newton Creek, Saint Louis River (St. Louis River AOC, and Howards Bay), Superior Bay (Hog Island Inlet), Faxon Creek and unnamed tributary are also proposed for impaired status.

- Description of actions municipality has taken to comply with section 1.5.2 of the MS4 general permit for discharges of pollutant(s) of concern to an impaired waterbody:

  Various water areas making up the St. Louis River and St. Louis Bay are listed as impaired water bodies with chemicals of concern including E. coli, Mercury, PCBs, PAHs, foam, oil slicks and unspecified metals. The City is developing a baseline of storm water loadings, so far we have tested outfalls draining into the Pickle Pond, Howard's Bay, and Tower Bay. In 2014 we tested outfalls draining into Allouez Bay and outfalls from Billings Park.
  Data has been provided to WDNR Superior as they are working on a remediation plan for these areas. There is continual public education efforts promoting picking up pet waste, properly maintaining cars, and proper disposal of mercury. This should have a positive impact to the impaired water bodies.

c. Identify any known water quality improvements in the receiving water to which the MS4 discharges during the reporting period.

None known

d. Identify any known water quality degradation in the receiving water to which the MS4 discharges during the reporting period and what actions are being taken to improve the water quality in the receiving water.

None known

SECTION IX. Proposed Program Changes

Describe any proposed changes to the storm water management program being contemplated by the municipality for 2015 and the schedule for implementing those changes. Proposed program changes must be consistent with the requirements of the general permit.

Changes planned at this time include updates to City Ordinances to comply with new state requirements.

SECTION X. Other

Any other additional information the permittee would like to provide in the Annual Report regarding their storm water program?

Faxon Creek:
Areas of the Faxon Creek Watershed were particularly hard hit during the extreme rainstorm of June 2012. Over two hundred properties were impacted and significantly damaged. In response the City initiated a study to develop a logical plan for the watershed with the goal of reducing flooding and property damage during significant rain events. The study included several elements such as hydraulic/hydrologic modeling of the watershed, capacity and condition assessment of major culverts, feasibility of stormwater best management practices and the development of several stormwater detention basin site alternatives. The study was conducted under contract by Donohue and Associates.
The K-Street Storm Sewer repair was identified as a high priority project. The roughly 10 foot diameter brick pipe provides over 2500 feet of conveyance for Faxon Creek before its terminus at the Lake Superior Bay. Maintaining its integrity is essential to help manage extreme rain events. Inspections identified several areas within the storm sewer

The K-Street project was completed in 2014 at a cost of just over $500,000.
The executive summary of the Faxon Watershed study is attached. The study cost the City over $100,000.

that required substantial repair and the damaged areas were continuing to deteriorate.
Repairs to the K Street storm sewer involved concrete lining, abandoned utility line removals and patching. This will improve the ability of the storm sewer to convey seasonal high water flows and reduce the extent of surface flooding.

SECTION X. Other (continued)

Additional repairs are currently being contemplated to include additional circumferential shotcrete lining and address additional isolated structural deficiencies noted in the structural inspection report. Additionally, improving the creek's flow capacity at other upstream culverts including Hill Avenue, the Soo Line Railroad, 21st Street, Caitlin Avenue have been identified as needed improvements to reduce the risk of upstream flooding in the Faxon Creek Watershed.

Central Business District:

The other area of widespread flooding was the Central Business District, a combined sewer area. The City has secured approximately $400,000 from WDNR for installation of a wet detention pond. We have also submitted a grant to EPA to convert the pond to a wetland basin through there green infrastructure program, we should hear back on this one shortly. This pond will take stormwater out of the combined system thereby reducing the demands on it and minimizing flooding.

Fiscal Analysis Table. Complete the fiscal analysis table provided below.

Program Element	Annual Expenditure 2014	Budget 2014	Budget 2015	Source of Funds
Public Education and Outreach	47,849	50,000	50,000	Stormwater Utility Impervious Area Fees
Public Involvement and Participation	48,089	50,000	50,000	Stormwater Utility Impervious Area Fees
Illicit Discharge Detection and Elimination	66,316	68,000	68,000	Stormwater Utility Impervious Area Fees
Construction Site Pollutant Control	57,413	65,000	65,000	Stormwater Utility Impervious Area Fees
Post-Construction Storm Water Management	88,024	96,000	96,000	Stormwater Utility Impervious Area Fees
Pollution Prevention	27,328	30,000	30,000	Stormwater Utility Impervious Area Fees
Storm Water Quality Management (including pollutant-loading analysis)	830,159	990,000	990,000	Stormwater Utility Impervious Area Fees
Storm Sewer System Map	24,696	29,000	29,000	Stormwater Utility Impervious Area Fees
Other: Utility Administration	417,230	477,000	477,000	Stormwater Utility Impervious Area Fees

NORTHERN REGION COUNTIES		
Ashland	Langlade	DNR Service Center
Barron	Lincoln	Attn: Storm Water Program
Bayfield	Oneida	5301 Rib Mountain Rd.
Burnett	Polk	Wausau, WI 54401
Douglas	Price	Phone: (715) 359-4522
Florence	Rusk	
Forest	Sawyer	
Iron	Taylor	
	Vilas	
	Washburn	

WEST CENTRAL REGION COUNTIES		
Adams	Marathon	DNR Service Center
Buffalo	Monroe	Attn: Storm Water Program
Chippewa	Pepin	5301 Rib Mountain Rd.
Clark	Pierce	Wausau, WI 54401
Crawford	Portage	Phone: (715) 359-4522
Dunn	St. Croix	
Eau Claire	Trempealeau	
Jackson	Vernon	
Juneau	Wood	
La Crosse		

NORTHEAST REGION COUNTIES		
Brown	Marquette	DNR Northeast Region
Calumet	Menominee	Attn: Storm Water Program
Door	Oconto	2984 Shawano Ave.
Fond du Lac	Outagamie	Green Bay, WI 54313
Green Lake	Shawano	Phone: (920) 662-5100
Kewaunee	Waupaca	
Manitowoc	Waushara	
Marinette	Winnebago	

SOUTH CENTRAL REGION COUNTIES		
Columbia	Jefferson	DNR South Central Region
Dane	LaFayette	Attn: Storm Water Program
Dodge	Richland	3911 Fish Hatchery Rd.
Grant	Rock	Fitchburg, WI 53711
Green	Sauk	Phone: (608) 275-3266
Iowa		

SOUTHEAST REGION COUNTIES		
Kenosha	Sheboygan	DNR Service Center
Milwaukee	Walworth	Attn: Storm Water Program
Ozaukee	Washington	141 NW Barstow Street,
Racine	Waukesha	Room 180
		Waukesha, WI 53188
		(262) 574-2100

2014 PEIR Activity Log

Month	Event	Date	Media	Activity/Information Distributed
	St. Louis River - our area of concern	1/2/2014	Webinar	Presented information on St. Louis river and ways to get involved in water protection
	Getting involved in protecting Lake Superior	1/6/2014	Webinar	Presented information on Lake Superior and ways to get involved in water protection
	Proper Disposal	1/20-2/27/2014	Display	Display at Government Center lobby
	What not to flush	1/20-2/27/2014	Display	Display at Mariner Mall cabinet
	Winter Road Salt	1/20-2/27/2014	Display	Display at Blaine Business Center cabinet
January	Stormwater Utility Newsletter	1/31/2014	Newsletter	Topics include: car car, native plants, composting, rain barrels, recap of ESD activities in 2013
	Senior Connections Health Expo	2/1/2014	Booth	Green cleaning display and distributed proper disposal of household materials
	Mercury and Stormwater table top tents	2/6/2014	Display	Distributed table top tents on mercury and general stormwater awareness to 3 local restaurants
	Water Film Night	2/13/2014	Film	Showed various water-related clips
	Puppet Show	2/24-4/3/2014	Presentation	Presented puppet show to over 20 classes from pre-K to 2nd graders on ways to help keep water clean
	Green cleaning display	2/27-4/1/2014	Display	Green Cleaning display at Government Center
	Pet waste display	2/27-3/28/2014	Display	Pet waste display at Blaine Business Center
February	Winter Road Salt Display	2/27-3/18/2014	Display	Winter road salt display at Mariner Mall
	Library Story Time	3/11/2014	Activity	Reading books on water - story time, Make flowers out of toilet paper
	Educational Fair	3/18/2014	Event	10 stations to educate Bryant and Cooper 5th Graders on water-related issues
	Streams of Superior	3/18-5/8/2014	Display	Streams of Superior display at Mariner Mall
	Lake Superior Bi-national Forum	3/28/2014	Booth	Display on ESD activities. Forum focused on "Mysteries of the Lake"
	Slow Down Water	3/28-4/29/2014	Display	Dislay on ways to slow down stormwater runoff at Blaine Business Center

March	Douglas County Fish & Game Show	3/28-3/30/2014	Booth	Provided information on mercury, fish consumption, stormwater awareness. Water wheel game to quiz visitors on water topics. Drawing for free car wash
	General Stormwater Awareness	4/1-4/25/2014	Display	Display on general stormwater at Government Center
	Girl Scouts Troop Meeting	4/3/2014	Activity	Discussed non-point source pollution and prevention with Enviroscape model. Made toilet paper flowers
	Science Night	4/11/2014	Booth	Stormwater display and modeled water pollution using Enviroscape
	Pollution Prevention Training	4/21-6/12-2014	Presentation	Training to City staff about good housekeeping, preventing and cleaning spills, who to contact
	World Book Night	4/23/2014	Booth	Display and brochures on Scoop the Poop
	Scoop the Poop with Rex	4/25/2014	Information	Rex the mascot dog waves and greeted people. Handed out bookmarks and poop bags. Gave materials to animal hospital, dog groomers and kennel
	Pet waste display	4/29-5/30/2014	Display	Pet waste display at Government Center
	Scoop the Poop	4/29/2014	Information	Promoted picking up pet waste at WITC
	Rain Barrels	4/29-5/30/2014	Display	Rain barrel display at Blaine Business Center
April	Let's Talk Healty Lawns	4/29/2014	Event	Provided speakers to talk about healthy yards, soils, and organic lawn care
	Wastewater Treatment Plant tours	5/7-6/6/2014	Presentation/ Activity	Gave tours to all Superior 5th Graders
	Organic Lawn Care display	5/8-6/27/2014	Display	Display on organic lawn care and native plants at Mariner Mall. Provided seed paper
	Earth Tracks	5/9/2014	Booth	Information and activity on the water cycle
	Fairlawn Garden Market	5/14/2014	Booth	Display on compost. Info on Native Plant list and Compost & soil classes. Drawing for compost bin
	E-waste display	5/30-6/25/2014	Display	E-waste display at Blaine Business Center. Provided handouts on proper disposal
	Rain Barrels	5/30-6/24/2014	Display	Rain barrel display at Government Center
May	Soil Samping & Home Compositng Workshop	5/31/2014	Event	Partnering with UW Ex Horticulturist, provided workshop on how to properly collecting soil samples for testing and beginners composting. Drawing for compost
	What not to flush	6/6/2014	Information	Talked with customers and Hardware store staff about What Not To Flush. Posted at store.

	Toilet Day	6/14/2014	Event	Stations to learn about wastewater treatment process and what not to flush
	Storm drain art reception and exhibit	6/14/2014	Event	Exhibit of 6 storm drain art from June 13- July 12
	Storm drain art information	6/24-722/2014	Display	Information on storm drain art, Government Center
	Lake Superior Day	6/25-7/25/2014	Display	Display promoting Lake Superior Day, Mariner Mall
June	Organic Lawn Care display	6/25-7/25/2014	Display	Display on organic lawn care and native plants at Blaine Business Center. Provided seed paper
	Farmer's Market	7/9/2014	Booth	Info on upcoming events - Lake Superior Day, Storm Drain Stenciling and Tour.
	Ice Cream Social	7/16/2014	Booth	Display geared towards kids on getting involved with water protection. Water wheel to quiz water knowledge
	Storm Drain Stenciling	7/17/2014	Activity	Boys & Girls Club, ages 6 and 7. Two adult helpers. We cleaned and stenciled over 20 drains.
	Lake Superior Day	7/20/2014	Booth	Activities for kids - butterfly pin, pin wheels, wordless water bracelets, Lake Superior tattoos
	Boaters keep lakes clean display	7/22-9/9/2014	Display	Info on cleaning boat but not damaging environment, keep trash on board. Government Center
	Reducing Soil Erosion	7/25-8/29/2014	Display	Reducing soil erosion display, Blaine Business Center
	Organic Lawn Care display	7/25/8/15/2014	Display	Display emphasizing native plants at Mariner Mall
	Tower Ave Grand Re-Opening	7/26/2014	Booth	Green infrastructure display for Tower Ave opening; rain barrel drawing and water wheelquizzing people
	Seed Ball	7/28/2014	Activity	Made a native plant seed balls with Parks & Rec youth. Also rolled large word dice and answered questions about water.
July	Stormwater Utility Newsletter	7/31/2014	Newsletter	Topics include: watersheds of Superior, beneficial compost critters, activities at ESD
	Free Lunch Program	8/4/2014	Activity	After youth and their parents ate lunch they came over to spin the water wheel and win prizes
	Wastewater Treatment Plant tour	8/7/2014	Event	Public tour about how wastewater is treated
	Free Lunch Program	8/14/2014	Activity	Nice range of ages rolled the dice and we talked about preventing water pollution. Goodies and prizes to all.

	Tour de Water Bus Tour	8/15/2014	Event	Public bus tour of Superior stormwater bmps: UWS green roof, Barkers Island rain garden, Billings Park detention pond, CVS store, Tower Ave.
	Storm drain art information	8/15-10/7/2014	Display	Storm drain art information at Mariner Mall
	Farmer's Market	8/20/2014	Booth	Promoted native plants and the Weed Walk Program. Household hazardous waste disposal and storm drain art and storm drain involvement
	Farmer's Market	8/23/2014	Booth	Promoted native plants and weed walk program. Gave native seed balls out. Storm Drain art and info on HHW disposal
	Weed Walk	8/23/2014	Event	2 weed walks were held and an indoor talk on invasive plants. Guest was Pam Roberts from the Weed Management program in Ashland.
August	Pollution Prevention display	8/29-10/7/2014	Display	Where to dispose of Household Hazardous Waste? Reduce and prevent pollution.
	Smart Start Resource Fair	9/2/2014	Booth	Display and handouts on general stormwater awareness
	Mercury display	9/9-10/7/2014	Display	Mercury, Proper Disposal, Items with Mercury
	Mercury display	9/12/2014-current	Display	Mercury display at 4 Boat Landings in Superior. Brochure on fish consumption
	Cause for Paws	9/13/2014	Booth	Promoted Scoop the Poop, handed out waste bags
	UW Extension County Youth Fair	9/13/2014	Booth	Simple display of "Keeping Lake Superior Blue." Activity was adaptation of "Would you drink this water?"
	Microplastics in water talk	9/17/2014	Event	Microplastics in oceans and Great Lakes. Plastic as beads and fiber.
	Showing of Waterlife video	9/18/2014	Event	The video goes into impacts on water of the Great Lakes and follows water through its journey out to the Atlantic. 109 minutes.
	East End Days	9/20/2014	Booth	Water Wheel and dice with questions to roll.
	Storm Drain Stenciling	9/26/2014	Activity	Stenciled 49 drains with club members
	Library Story Time	9/30/2014	Activity	Read 3 books - Fish is Fish, Rain, Water Drop Journey. Made fish prints
September	Fish Print craft	9/30/2014	Activity	Made fish prints at Senior Center
	Pollution Prevention	10/1/2014	Presentation	Talk about ESD activities and interactive steps to pollution prevention at Optimist Club

	Protect Our Waters Fun Fair	10/6/2014	Event	12 water-themed game stations. Involved local businesses and organizations and ESD ran 5 of the stations.
	Green cleaning display	10/7-11/10/2014	Display	Green cleaning display at Blaine Business Center. Brochures on non-toxic cleaning recipes
	Conserve water display	10/7-11/10/2014	Display	Display on water conservation tips at Government Center. Provided leaky toilet test tablets
	Mercury display	10/7-11/14/2014	Display	Mercury display at Mariner Mall
	School visit - Enviroscape	10/10/2014	Activity	A station for 4th Graders dicussing non-point source pollution and how to prevent it in watershed.
	School visit	10/10/2014	Activity	4th garders. Morning class went storm drain stenciling. Mid-day class did the water drop and sticky water.
	School visit - learning stations	10/14 & 10/17/2014	Activity	Northern Lights 5th graders. Station on rain gardens/rain barrels/how much water/local streams. Station on EnviroScape - nonpoint source pollutants
	Pumpkin Patch	10/18/2014	Booth	Made "litter bugs" as a reminder not to litter. Had a flip book of "Where does it belong? Trash, Recycle, Compost". Handouts geared towards kids about litter and stormwater
	School visit - chemistry class	10/20/2014	Presentation	Presented on stormwater pollution, what is stormwater
	Moose Club	10/23/2014	Presentation	Talk on stormwater pollution prevention, proper disposal
October	School visit - Enviroscape	10/27/2014	Activity	Discuss watershed, water pollution & prevention with 3rd grade class.
	Lake Superior Jeopardy	11/3/2014	Activity	Jeopardy at Senior Center. Had 5 categories with 4 questions each. Water Use, Lake Superior, Local Waters, Pollution Prevention, What's the Difference
	Mercury display	11/10-12/16/2014	Display	Mercury display at Blaine Business Center
	Green cleaning display	11/10-12/16/2014	Display	Green cleaning display at Government Center. Brochures on non-toxic cleaning recipes
	Fats, Oils, Grease	11/14-12/16/2014	Display	Display at Mariner Mall on what on fats, oils, grease. Handouts on maintaining sewer health

November	Let's Talk Recycling II	11/17/2014	Event	Guest speakers on City code compliance, SIMKO, Como Lube & Supplies (car and ewaste)
December	How plants help reduce stormwater flow	12/10/2014	Presentation	Program to Master Gardeners with information on rain gardens, rain barrels, how much water comes in a storm, benefits of plants on water quality
	Road Salt display	12/16/2014-	Display	Proper use of winter salt display at Government Center
	Pet waste display	12/16/2014-	Display	Pet waste display at Mariner Mall
	Protect our waters display	12/16/2014-	Display	Stormwater protection tips in winter display at Blaine Business Center

RSPT Activity Log for 2014

Activity	Date	Location	# of Participants	Comments
Monthly Meeting	January 15, 2014	City of Duluth	20	
MPCA Annual - Collection System Operators	January 28, 2014	Brooklyn Park (local operators attend)	100	stormwater mgmt and flood recovery
Innovative Conference Presentation	February 11, 2014	St Cloud Holiday Inn (local operators)	100	stormwater mgmt and flood recovery
Monthly Meeting	February 19, 2014	City of Duluth	20	
Monthly Meeting	March 19, 2014	City of Duluth	20	
St Louis Riverwatch Spring Congress	March 20th, 2014	Fond du Lac Community College		multiple presentations from RSPT members
Home Show	April 2-6	DECC Arena		
Your Green Life segment	April 2 & 3, 2014	NNC		
Turf Maintenance Workshop	April 3rd, 2014	UWS	40	
Monthly Meeting	April 16th, 2014	WLSSD	24	
Public Event: MS4 Annual Meeting (Duluth, LSC, MNDOT, St. Louis County)	June 26th	City of Duluth Garfield		Duluth, Hermantown, LSC, St Louis Cty, MNDOT attended
School Event: Earth Tracks	May 2, 2014	Lake Superior Zoo	1000+	Duluth, WLSSD, Superior, others attended
Article - Spring runoff - Duluth News Tribune	May 5, 2014	Duluth News		
Hartley Nature Center Youth Outdoor Expo	May 3, 2014	Hartley Nature Center		multiple RSPT members attended
School Event: River Quest	May 12-15	St Louis River, DECC	1400+	multiple RSPT members attended
Monthly Meeting	May 21st	NRRI		
WLSSD and RSPT Rain Barrel and Compost Bin Truckload Sale	May 17, 2014	Lake Superior College, Duluth	660	
Monthly Meeting	June 18th, 2014	City of Superior		tour of Superior WWTP
All Pints North Summer Brew Festival	July 26, 2014	Bayfront Park, Duluth		
Monthly Meeting	July 16th	UMD	23	tour of lakewood water plant
Hermantown Summer Fest	July 16-20, 2014	Hermantown		
Lake Superior Days	July 20th, 2014	Duluth News		
Art in the Park	August 15-16 2014	Duluth Area		
Monthly Meeting	August 20th	WLSSD (tour)		
Lake Superior Dragon Boat Festival	August 23rd	Park Point Duluth		
County Fairs in RSPT area	all summer	Various		WLSSD attends
Music and Movies in the Park	all summer	Chester Park, Bayfront, Leif Erickson, others.		
Event: 2014 Harvest Festival and Energy Fair	September 6, 2015	Bayfront Park, Duluth		
Monthly Meeting	September 17th	St Louis County	19	
Monthly Meeting	October 15th	Superior		
Monthly Meeting	November 19th	MNDOT		
Monthly Meeting	December 17th	Comfort Systems, Duluth		

Illicit Discharge Detection and Elimination

The City has met two measurable goals of (1) implementing an Illicit Discharge Ordinance since 2010 and (2) performing initial field screening of all 19 major outfalls. The on-going best management practice [bmp] is continual field screening of outfalls (annual screening of 50% major and 20% minor outfalls).

Illicit Discharge Field Screening

The City successfully met our measurable goal of field screening 50% of the major outfalls and 20% of minor outfalls (9 and 18, respectively) for illicit discharge in 2014. Screening occurred 48 hours after the last runoff-producing precipitation event and included visual observation of color, odor, oil sheen/surface scum, outfall damage, visible flow, and other relevant observations regarding the potential presence of non-stormwater discharges. Flow was observed for 8 major and 3 minor outfalls and analyzed to determine potential illicit discharge source.

All outfalls screened in 2014 were successfully located. Other than observed flow, none of the major outfalls screened had any other visible issues. There were a few issues with the screened minor outfalls: 2 of the minor ones were mislabeled as outfalls; 2 minor outfalls were buried under ground/sediment (likely due to the 2012 flood); 1 minor outfall was privately extended; and 1 minor outfall had recently been combined with a nearby major outfall. Maintenance and cleaning requests were sent at the end of the field season to address these issues. A request to update storm sewer maps was also sent.

A summary of the 2014 Field Screening can be found in the Illicit Discharge Field Screening Activity tables.

Illicit Discharge Response

During 2014 field screening, the 11 outfalls (8 major, 3 minor) that were identified as having potential illicit discharge concerns were sampled and analyzed for potential flow sources. Stormwater flow was analyzed for detergents, potassium, fluoride, and ammonia. Using the CWP IDDE Manual's Flow Chart, all flows were determined to be from natural water source (4 major, 2 minor) or irrigation source (4 major, 1 minor). None of the flows tested positive for sanitary or washwater contamination. Given the clay soils in the area, it is likely natural rain water from a previous precipitation event was slowly being released by the surrounding clay. Details of results are found in Illicit Discharge Flow Results for 2014 table.

A hotline is maintained for citizen reporting of suspected illegal dumping or illicit discharge. There were 8 reports of illicit discharge. Staff investigated and responded to all reports. Responsible parties were determined and notified if necessary.

Illicit Discharge Field Screening Activity Summary 2014

Major Outfall ID	Field Screening Date	Flowing *	Maintenance/ Cleaning Required	Crew Notified Date; Maintenance Date	Comments	Sample Results**
OT3A0005	Sept. 17, 2014	X				Likely natural water source
OT3A0038	Sept. 8, 2014	X				Likely tap/irrigation water source
OT3A0251	Sept. 18, 2014	X				Likely natural water source
OT3B0026	Aug. 6, 2014	X				Likely tap/irrigation water source
OT3B0027	Aug. 6, 2014	X				Likely tap/irrigation water source
OT020010	Aug. 6, 2014	X				Likely natural water source
OT020012	Aug. 5, 2014					N/A
OT040009	Sept. 9, 2014	X				Likely tap/irrigation water source
OT050001	Sept. 16, 2014	X				Likely natural water source

Minor Outfall ID	Field Screening Date	Flowing *	Maintenance/ Cleaning Required	Collection Crew Notified; Maintenance Date	Comments	Sample Results**
OT3B0028	Oct. 9, 2014					N/A
OT3B0212	Aug. 6, 2014				*Combined with OT3B0027*	N/A
OT010185	Oct. 15, 2014		X	Nov. 13, 2014	Buried	N/A
OT040206	Oct. 16, 2014					N/A
OT040216	Nov. 6, 2014					N/A
OT040224	Sept. 18, 2014	X				Likely natural water
OT050017	Aug. 6, 2014					N/A
OT050018	Aug. 6, 2014		X	Nov. 13, 2014		N/A

OT060001	Aug. 5, 2014					N/A
OT060020	Oct. 8, 2014				Privately extended outfall	N/A
OT060058	Aug. 5, 2014				*NOT AN OUTFALL*	N/A
OT060068	Aug. 5, 2014					N/A
OT070006	Aug. 8, 2014	X				Likely tap/irrigation water source
OT070089	Nov. 6, 2014		X	Nov. 13, 2014		N/A
OT08001A	Aug. 8, 2014	X				Likely natural water source
OT080156	Oct. 22, 2014		X	Nov. 13, 2014	Buried	N/A
OT080162	Oct. 16, 2014					N/A
OT090001	Sept. 16, 2014				*NOT AN OUTFALL*	N/A

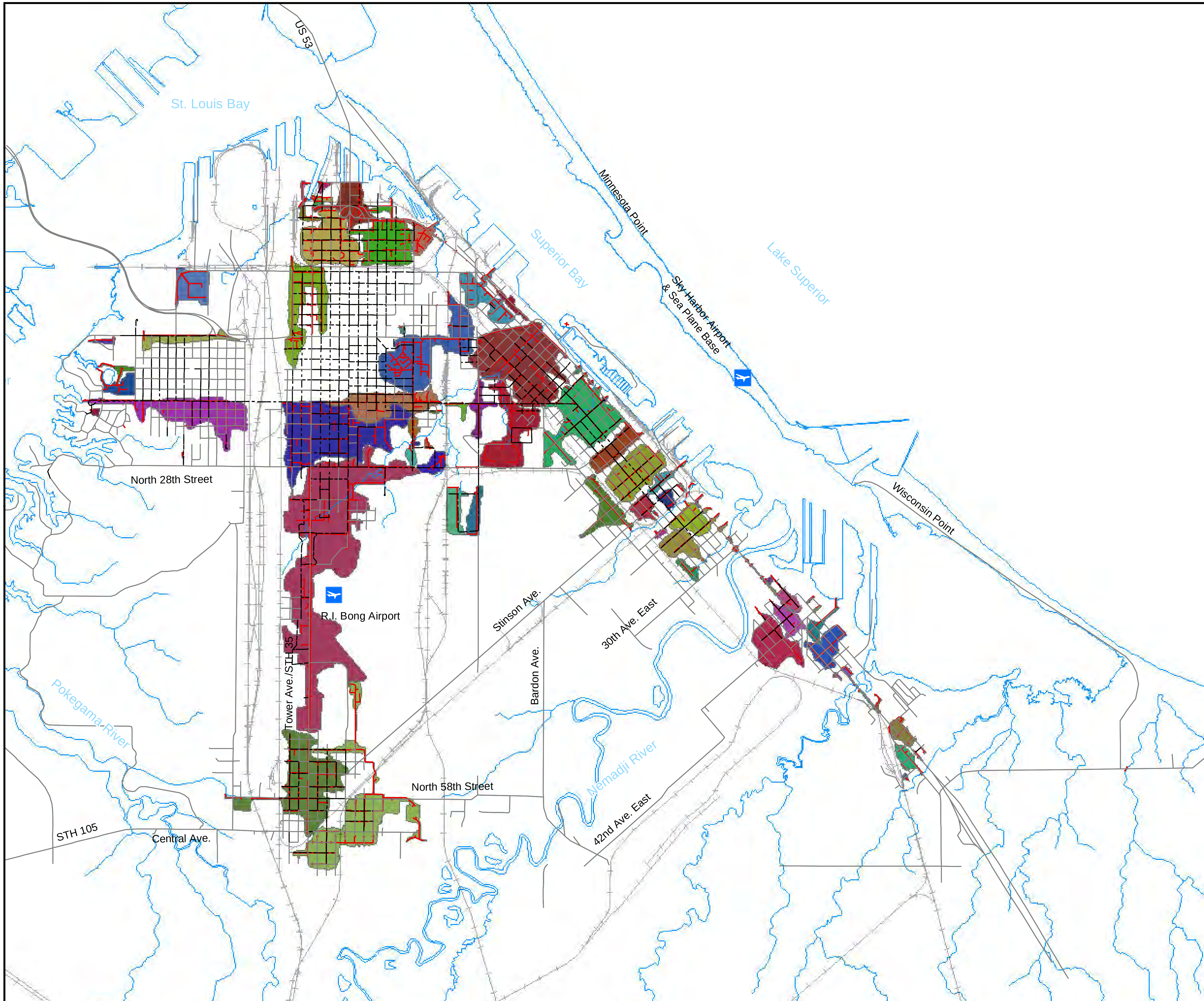
Illicit Discharge Flow Results for 2014

Outfall ID	Sample Time	Analysis Location	Parameter	Results (mg/L)	Analysis Date	Analysis Time	Method	Analyzed By/ Results Approved By	Possible Contamination?
OT3B0026	8/6/2014 10:00	Field	Detergents	<1.0 PPM	8/6/2014	10:00	LaMotte , DS-1	Wendy Grethen	Likely tap/irrigation water source
		Era Lab	Fluoride	0.4	8/17/2014	0:21	EPA 300.0 Rev. 2.1	Laura Mae Lubahn (ERA)	
		Era Lab	Nitrogen, Ammonia	<0.06	8/7/2014	10:30	SM 4500-NH3 D-97 OL		
		Era Lab	Potassium, Total	4.6	8/19/2014	14:59	EPA 200.7 Rev. 4.4		
OT3B0027	8/6/2014 10:30	Field	Detergents	<1.0 PPM	8/6/2014	10:30	LaMotte , DS-1	Wendy Grethen	Likely tap/irrigation water source
		Era Lab	Fluoride	0.3	8/17/2014	0:35	EPA 300.0 Rev. 2.1	Laura Mae Lubahn (ERA)	
		Era Lab	Nitrogen, Ammonia	<0.06	8/7/2014	10:30	SM 4500-NH3 D-97 OL		
		Era Lab	Potassium, Total	6.5	8/19/2014	15:04	EPA 200.7 Rev. 4.4		
OT020010	8/6/2014 11:30	Field	Detergents	<1.0 PPM	8/6/2014	11:30	LaMotte , DS-1	Ada Tse	Likely natural water source
		Era Lab	Fluoride	0.2	8/17/2014	0:06	EPA 300.0 Rev. 2.1	Laura Mae Lubahn (ERA)	
		Era Lab	Nitrogen, Ammonia	<0.06	8/7/2014	10:30	SM 4500-NH3 D-97 OL		
		Era Lab	Potassium, Total	5.6	8/19/2014	14:57	EPA 200.7 Rev. 4.4		
OT08001A	8/8/2014 11:30	Field	Detergents	<1.0 PPM	8/8/2014	11:30	LaMotte , DS-1	Ada Tse	Likely natural water source
		Era Lab	Fluoride	0.2	8/17/2014	1:03	EPA 300.0 Rev. 2.1	Laura Mae Lubahn (ERA)	
		Era Lab	Nitrogen, Ammonia	<0.06	8/13/2014	10:57	SM 4500-NH3 D-97 OL		
		Era Lab	Potassium, Total	26.7	8/19/2014	16:50	EPA 200.7 Rev. 4.4		
OT070006	8/8/2014 12:05	Field	Detergents	<1.0 PPM	8/8/2014	12:05	LaMotte , DS-1	Asher Fink	Likely tap/irrigation water source
		Era Lab	Fluoride	0.4	8/17/2014	2:04	EPA 300.0 Rev. 2.1	Laura Mae Lubahn (ERA)	
		Era Lab	Nitrogen, Ammonia	<0.06	8/13/2014	10:57	SM 4500-NH3 D-97 OL		
		Era Lab	Potassium, Total	6.4	8/19/2014	16:53	EPA 200.7 Rev. 4.4		
OT3A0038	9/8/2014 10:00	Field	Detergents	<1.0 PPM	9/8/2014	10:00	LaMotte , DS-1	Asher Fink	Likely tap/irrigation water source
		Era Lab	Fluoride	0.4	9/10/2014	2:07	EPA 300.0 Rev. 2.1	Laura	

		Era Lab	Nitrogen, Ammonia	0.08	9/11/2014	10:11	SM 4500-NH3 D-97 OL	Mae Lubahn (ERA)	
		Era Lab	Potassium, Total	3.7	9/18/2014	10:45	EPA 200.7 Rev. 4.4		
OT040009	9/9/2014 14:00	Field	Detergents	<1.0 PPM	9/9/2014	14:00	LaMotte , DS-1	Ada Tse	Likely tap/irrigation water source
		Era Lab	Fluoride	0.5	9/15/2014	23:59	EPA 300.0 Rev. 2.1	Laura Mae Lubahn (ERA)	
		Era Lab	Nitrogen, Ammonia	0.06	9/11/2014	10:11	SM 4500-NH3 D-97 OL		
		Era Lab	Potassium, Total	3	9/18/2014	10:48	EPA 200.7 Rev. 4.4		
OT050001	9/16/2014 12:40	Field	Detergents	<1.0 PPM	9/16/2014	12:40	LaMotte , DS-1	Ada Tse	Likely natural water source
		Era Lab	Fluoride	0.2	9/16/2014	15:45	EPA 300.0 Rev. 2.1	Laura Mae Lubahn (ERA)	
		Era Lab	Nitrogen, Ammonia	< 0.06	9/23/2014	11:35	SM 4500-NH3 D-97 OL		
		Era Lab	Potassium, Total	4	9/24/2014	10:55	EPA 200.7 Rev. 4.4		
OT3A0005	9/17/2014 10:31	Field	Detergents	<1.0 PPM	9/17/2014	10:31	LaMotte , DS-1	Ada Tse	Likely natural water source
		Era Lab	Fluoride	< 0.1	9/19/2014	17:37	EPA 300.0 Rev. 2.1	Laura Mae Lubahn (ERA)	
		Era Lab	Nitrogen, Ammonia	< 0.06	9/23/2014	11:35	SM 4500-NH3 D-97 OL		
		Era Lab	Potassium, Total	1.6	9/24/2014	11:06	EPA 200.7 Rev. 4.4		
OT3A0251	9/18/2014 12:06	Field	Detergents	<1.0 PPM	9/18/2014	12:06	LaMotte , DS-1	Ada Tse	Likely natural water source
		Era Lab	Fluoride	0.2	9/19/2014	18:06	EPA 300.0 Rev. 2.1	Laura Mae Lubahn (ERA)	
		Era Lab	Nitrogen, Ammonia	0.07	9/25/2014		SM 4500-NH3 D-97 OL		
		Era Lab	Potassium, Total	2.2	9/24/2014	11:12	EPA 200.7 Rev. 4.4		
OT040224	9/18/2014 11:15	Field	Detergents	<1.0 PPM	9/18/2014	11:15	LaMotte , DS-1	Asher Fink	Likely natural water source
		Era Lab	Fluoride	< 1	9/19/2014	19:54	EPA 300.0 Rev. 2.1	Laura Mae Lubahn (ERA)	
		Era Lab	Nitrogen, Ammonia	0.11	9/25/2014		SM 4500-NH3 D-97 OL		
		Era Lab	Potassium, Total	9	9/24/2014	11:09	EPA 200.7 Rev. 4.4		

City of Superior Stormwater Structures

LEGEND	POND TYPE	X	Y	SIZE (Acres)
South Superior Water Quality Pond	Wet	151093.3553	286147.0477	3.2
Butler Pond	Dry	144274.3157	286515.4983	3.8
Bong Airport	Dry	147126.9264	293809.7827	2.2
Grandview Estates	Dry	139195.6088	304186.7198	1
Vinje Industrial Park	Dry	141660.212	308044.217	1
Barkers Island 2	Wet	158928.3688	304856.532	0.6
Barkers Island 1	dry	159862.7136	303959.6072	0.3
CSTP5	dry	151152.1624	284915.845	6
Landfill	dry	182450.5651	287750.1678	2
CSTP2	wet	155149.5674	308382.9045	13.6
CSTP6	dry	138807.2907	303875.0586	6.6
Billings Park	wet	139911.3632	302381.3606	1.8
Grit Chamber	DCHAMBER	138730.5249	303306.682	NA
Grit Chamber	DCHAMBER	139345.9209	304139.8899	NA
Grit Chamber	DCHAMBER	139145.7081	303466.0921	NA
Grit Chamber	DCHAMBER	152317.7201	300612.9219	NA
Grit Chamber	DCHAMBER	141595.7038	306986.672	NA
Grit Chamber	DCHAMBER	157344.0372	305943.0871	NA
Grit Chamber	DCHAMBER	146973.6258	310261.6825	NA
Grit Chamber	DCHAMBER	147151.8984	309790.4843	NA
Grit Chamber	DCHAMBER	147148.9221	309324.1561	NA
Grit Chamber	DCHAMBER	147146.2311	308904.758	NA
Grit Chamber	DCHAMBER	147139.634	308530.1052	NA
Grit Chamber	DCHAMBER	147072.748	307963.1326	NA



THE CITY OF
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Figure 2.8.1.A
Drainage Basin Boundaries For Each MS4 Outfall; Storm Water Conveyence System

Legend

SewerShed Outfall

OT010004
OT010005
OT010006
OT010007
OT010008
OT010009
OT010066
OT010150
OT010307
OT020004
OT020010
OT020012
OT020236
OT021021
OT040001
OT040004
OT040005
OT040006
OT040007
OT040009
OT040010
OT040011
OT040014
OT040121
OT040135
OT040191
OT040199
OT040202
OT040206
OT040211
OT040216
OT040221
OT040224
OT040233
OT040235
OT040237
OT040239
OT040241
OT040257
OT050001
OT050016
OT050017
OT050018
OT060001
OT060003
OT060004
OT060020
OT060060
OT060066
OT060068
OT060139
OT060142
OT070001
OT070006
OT070012
OT070013
OT070014
OT070021
OT070024
OT070025
OT070085
OT070087
OT070089
OT070111
OT070180
OT070183
OT070187
OT070194
OT080001
OT080002
OT08001A
OT080140
OT080152
OT080162
OT080163
OT080166
OT090000
OT3A0005
OT3A0038
OT3A0212
OT3A0235
OT3A0243
OT3A0246
OT3A0251
OT3A0281
OT3A0290
OT3A0303
OT3A0315
OT3A0316
OT3A0321
OT3A0322
OT3A175A
OT3B0026
OT3B0027
OT3B0028
OT3B0220
OT3B0229
OT3B0233
OT3B0315
OT3B0330

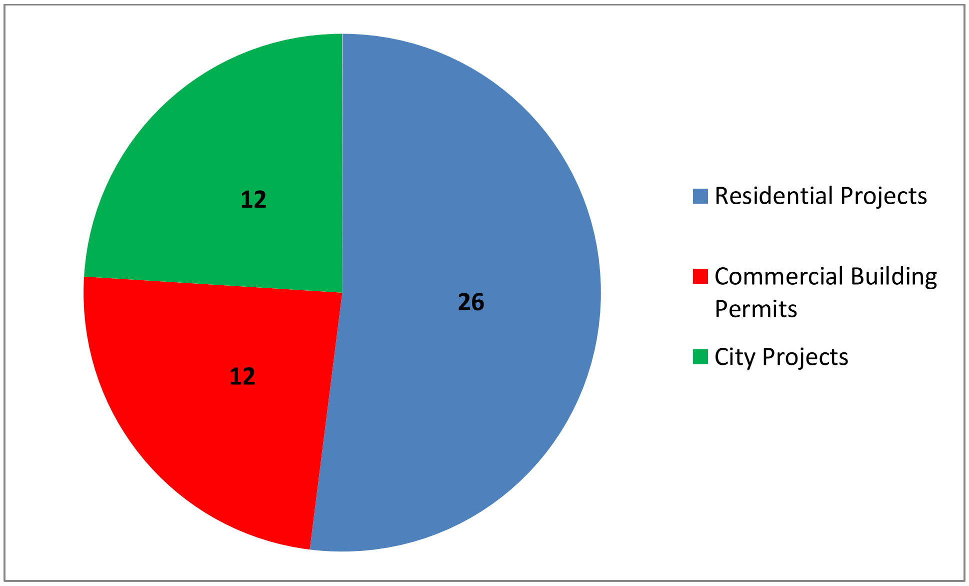
Storm Sewer
Street w/no curb
Street w/curb on one side
Street w/curb on both sides

0 0.5 1 2 Miles

Date: 2/16/2015

Erosion Control Information for Annual Stormwater Report

The total number of erosion control permits that were issued and approved by the City of Superior for the year 2014 was 50 permits. Among those, 12 were City of Superior projects and 38 that were private contractors and land owners. The non-City projects were divided into two main categories: Commercial buildings and residential projects. There were 26 residential project permits issued in the year of 2014 versus 12 permits that covered commercial buildings. Chart below summarizes the permits breakdown.



The City of City of Superior coordinates with project owners and managers the dates of field inspection prior to issuing erosion control permits. Field inspections aim at enforcing the original erosion control practices that were approved by the City at the time of application review. If field conditions changed after permit review, the City always finds the best practical solution to accommodate for the change and maintain a good control on preventing any possible erosion.

The vast majority of the projects that were executed within the City limits go as planned. If field inspections reveal any alteration or potential to soil erosion, the City always alerts the project owner immediately to gain control on situation and address the concern immediately. This is being implemented by either: phone or email and a formal letter whichever is faster. If in certain circumstances, there was no cooperation form the project manager or owner, the City takes this a step further and issue a citation. The City of Superior has been successful in containing the action required in the first phase with additional field inspections as required.

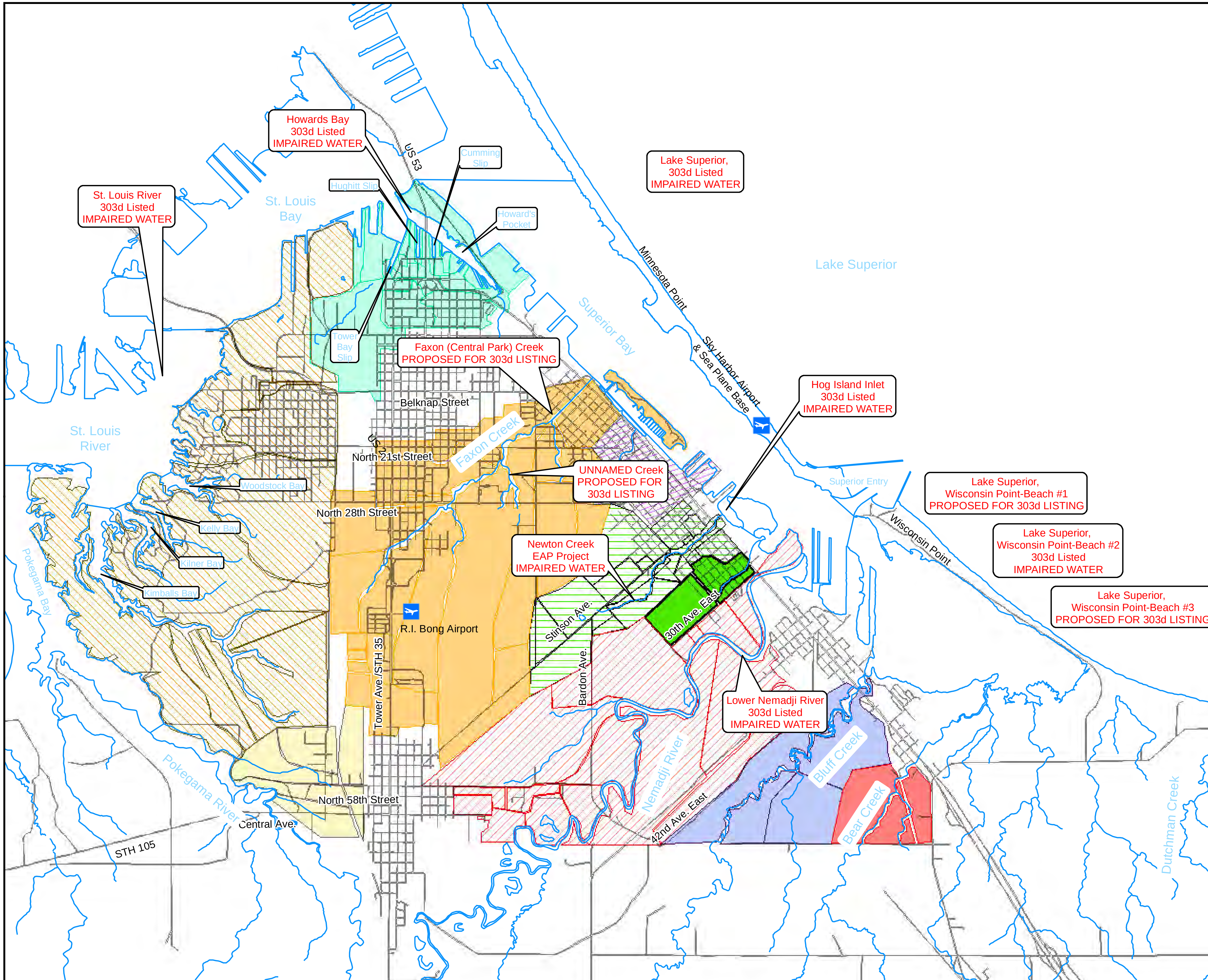


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Figure 2.8.1.B
ORW, ERW, and Impaired Waters; Receiving Waters; Watersheds

Date: 2/16/2015

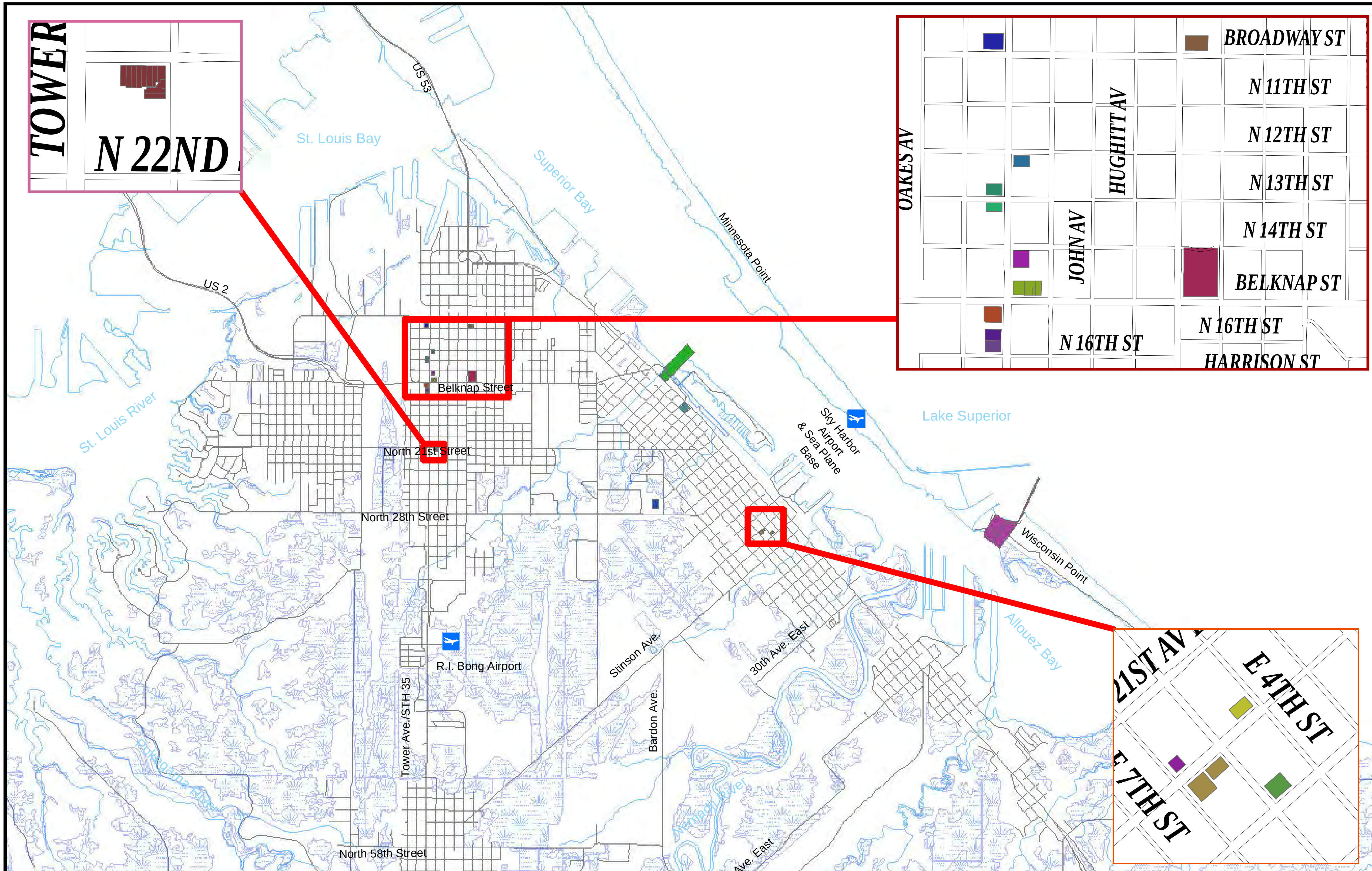

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Figure 2.8.2
Threatened
&
Endangered Resources, Historical Property, and Wetlands

0 0.5 1 2 Miles

Date: 2/20/2015

Legend

Historical Properties

HIS_Name

- Berkshire Block
- Descent Block
- Douglas County Courthouse
- Empire Block
- METEOR (Whaleback carrier)
- Maryland Block
- Massachusetts Block
- Minnesota Block-Board of Trade Bldg.
- New Jersey Building
- New York Block
- Northern Block
- Pattison, Martin, House
- Roosevelt Terrace
- St. Joseph Orphan Home
- Superior Entry South Breakwater Light
- Trade and Commerce Building
- Washington Block
- Wemyss Building

Wetlands

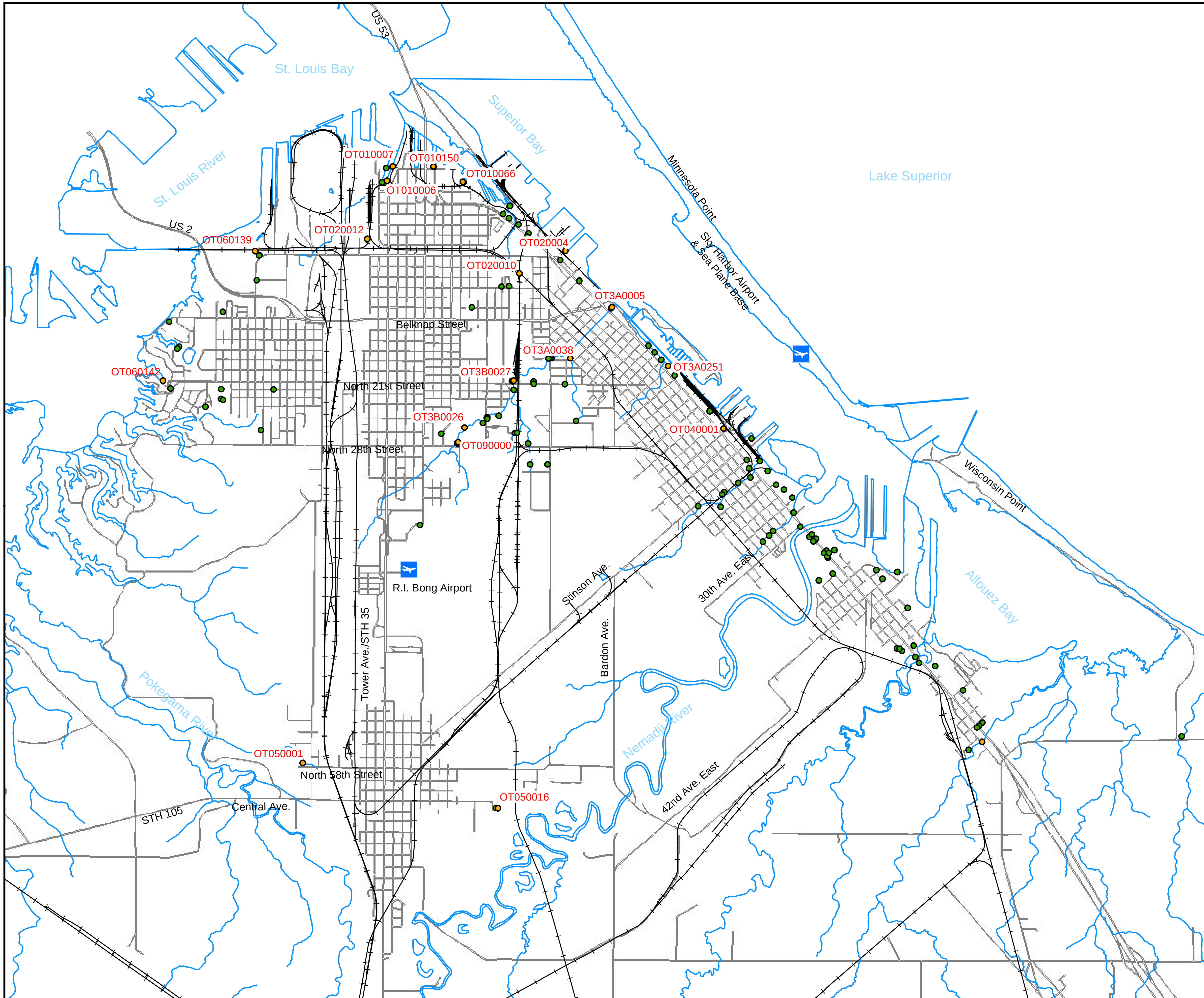

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Figure 2.8.3
Known MS4 Outfalls

Legend

- Major Outfalls
- Minor Outfalls
- railroads
- Streets

0 0.5 1 2 Miles

Date: 2/17/2015

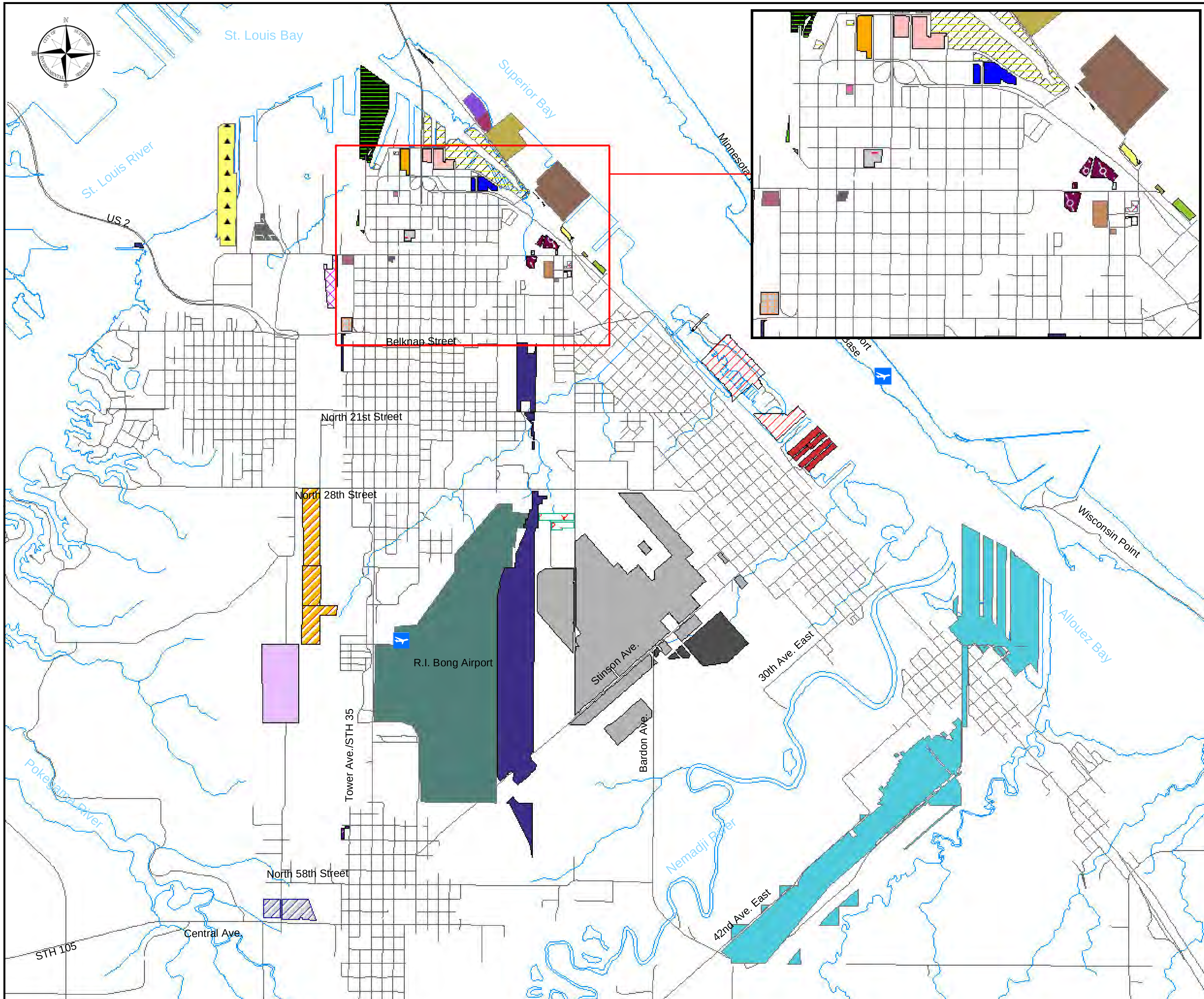

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Figure 2.8.4
WPDES Permit Holders

Permittees

BARKER'S ISLAND MARINA
AMSOIL
BARKO HYDRAULICS, INC
BNSF - SUPERIOR YARD
BNSF ALLOUEZ
CALUMET SUPERIROR LLC
CITY OF SUPERIOR - TREE DUMP
DAVE EVANS TRANSPORT INC
DAVE EVANS TRANSPORTS
DAVE EVANS TRANSPORTS INC
DOME PETROLEUM
FRASER SHIPYARDS INC
GENISIS ATTACHMENTS
GRAYMONT (WI) LLC
HALLETT DOCK COMPANY
HALVOR LINES INC
HANSEN MEULLER COMPANY
IHS DEVELOPMENT
J & B TRUCKING LLC
JEFF FOSTER TRUCKING
JEFF FOSTER TRUCKING INC
LAKEHEAD CONCRETE WORKS
METAL RECOVERY CORP
MONRCH PAVING COMPANY
NORTHERN ENGINEERING WORKS
O S I ENVIRONMENTAL INC
PETERSON WOOD TREATING
RICHARD I. BONG AIRPORT
SIMKO SUPERIOR, LTD
SIMKO-SUPERIOR LTD
SOO LINE
SPECIALITY MINERALS INC.
STELLA-JONES CORP
SUPERIOR-DULUTH REDI-MIX INC
T.L.K. INDUSTRIES, INC.
TWIN PORTS AUTO PARTS
UNION PACIFIC RILROAD-ITASCA YARD
VALLEY CARTAGE & WAREHOUSING
WMRA - RECYCLING CENTER
WOODLINE MANUFACTURING
WORLDWIDE

0 0.45 0.9 1.8 Miles

Date: 2/24/2015

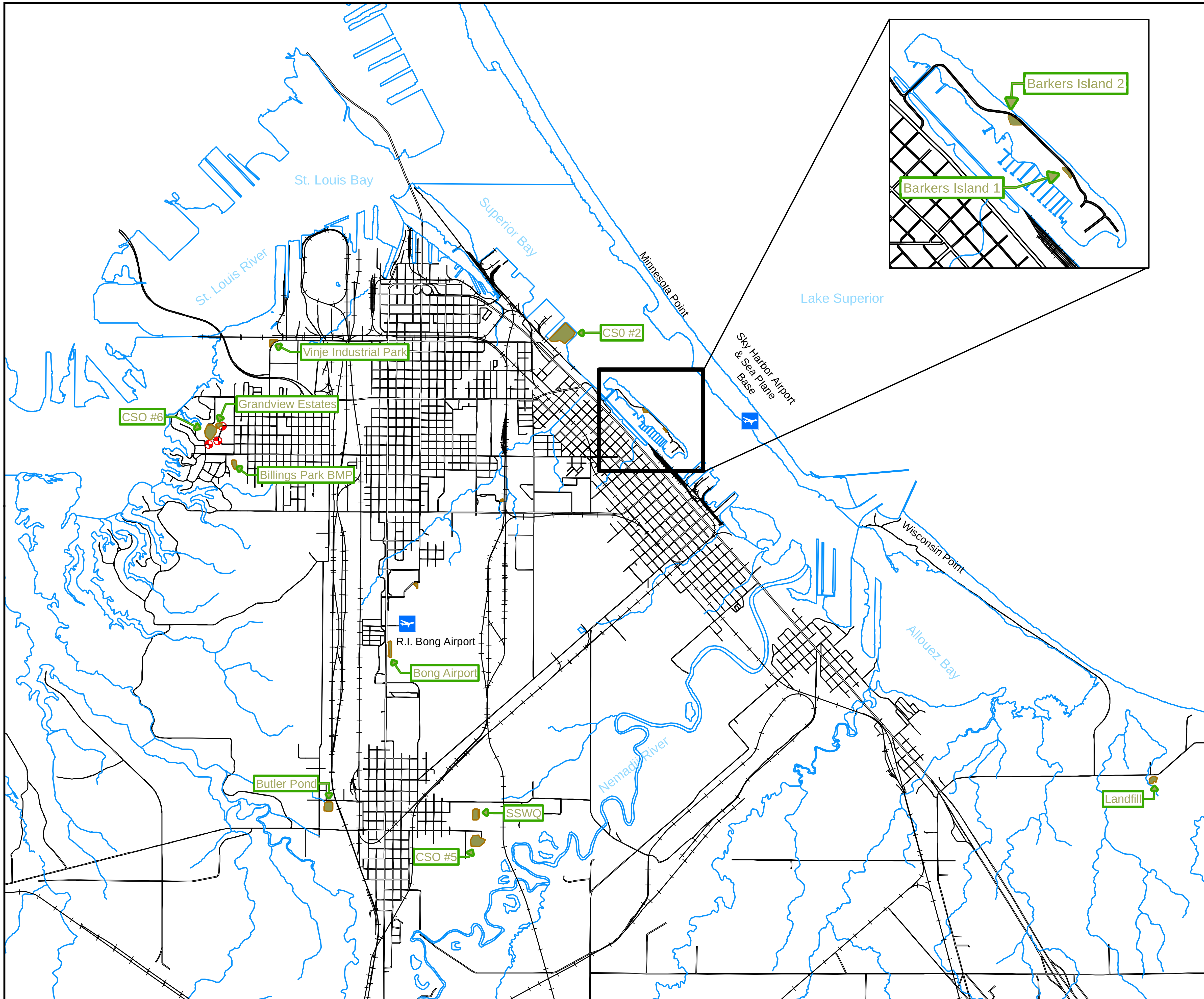

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Figure 2.8.5
Municipally Owned and Operated Stormwater Management Facilities

Legend

- Detention_Basins
- Grit Chamber
- railroads
- Streets

0 0.5 1 2 Miles

Date: 2/17/2015

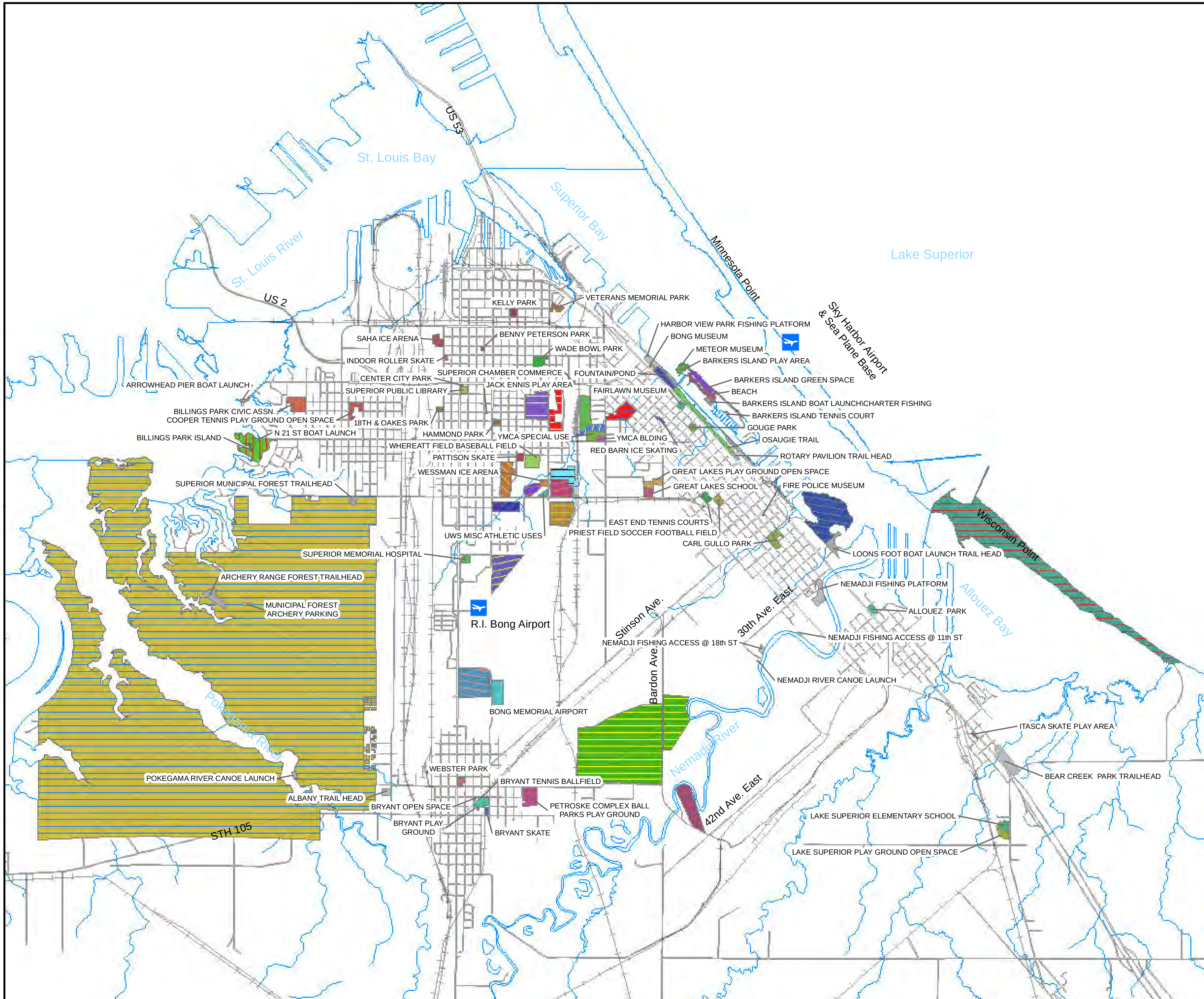

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Figure 2.8.6 Publicly Owned Parks and Other Recreational Areas

Legend

- 18TH & OAKES PARK
- ALBANY TRAIL HEAD
- ALLOUEZ PARK
- ARCHERY RANGE FOREST TRAILHEAD
- ARROWHEAD PIER BOAT LAUNCH
- BARKERS ISLAND BOAT LAUNCH\CHARTER FISHING
- BARKERS ISLAND GREEN SPACE
- BARKERS ISLAND PLAY AREA
- BARKERS ISLAND TENNIS COURT
- BEACH
- BEAR CREEK PARK TRAILHEAD
- BENNY PETERSON PARK
- BILLINGS PARK CIVIC ASSN.
- BILLINGS PARK ISLAND
- BILLINGS PARK PROPER
- BONG MEMORIAL AIRPORT
- BONG MUSEUM
- BRYANT OPEN SPACE
- BRYANT PLAY GROUND
- BRYANT SKATE
- BRYANT TENNIS BALLFIELD
- CARL GULLO PARK
- CENTER CITY PARK
- CENTRAL PARK
- COOPER TENNIS PLAY GROUND OPEN SPACE
- EAST END TENNIS COURTS
- FAIR GROUNDS RACE TRACK CURLING CLUB
- FAIRLAWN MUSEUM
- FIRE POLICE MUSEUM
- FOUNTAIN/POND
- GOUGE PARK
- GREAT LAKES PLAY GROUND OPEN SPACE
- GREAT LAKES SCHOOL
- HAMMOND PARK
- HARBOR VIEW PARK FISHING PLATFORM
- HAUGSRUD FIELD TENNIS
- HAYES CT COMPLEX BALL FIELDS
- HAYES CT COMPLEX RAVINE
- HERITAGE PARK
- HOG ISLAND
- INDOOR ROLLER SKATE
- ITASCA SKATE PLAY AREA
- JACK ENNIS PLAY AREA
- KELLY PARK
- LAKE SUPERIOR ELEMENTARY SCHOOL
- LAKE SUPERIOR PLAY GROUND OPEN SPACE
- LOONS FOOT BOAT LAUNCH TRAIL HEAD
- METEOR MUSEUM
- MUNICIPAL FOREST ARCHERY PARKING
- MUNICIPAL FOREST CC SKIING HIKING BIKING
- N 21 ST BOAT LAUNCH
- NEMADJI FISHING ACCESS @ 11th ST
- NEMADJI FISHING ACCESS @ 18th ST
- NEMADJI FISHING PLATFORM
- NEMADJI GOLF
- NEMADJI RIVER CANOE LAUNCH
- NEMADJI SLED
- OSAUGIE TRAIL
- PATTISON SKATE
- PETROSKE COMPLEX BALL PARKS PLAY GROUND
- POKEGAMA RIVER CANOE LAUNCH
- PRIEST FIELD SOCCER FOOTBALL FIELD
- RED BARN ICE SKATING
- ROTARY PAVILION TRAIL HEAD
- SAHA ICE ARENA
- SHS BFIELDS TENNIS PRATICE FOOTBALL
- SOCCER COMPLEX
- SUPERIOR CHAMBER COMMERCE
- SUPERIOR MEMORIAL HOSPITAL
- SUPERIOR MIDDLE SCHOOL
- SUPERIOR MUNICIPAL FOREST TRAILHEAD
- SUPERIOR NORTHERN LIGHTS SCHOOL
- SUPERIOR PUBLIC LIBRARY
- SUPERIOR SENIOR HIGH SCHOOL
- UWS CAMPUS
- UWS MISC ATHLETIC USES
- UWS TRACK AND FIELD
- VETERANS MEMORIAL PARK
- WADE BOWL PARK
- WEBSTER PARK
- WESSMAN ICE ARENA
- WHEREATT FIELD BASEBALL FIELD
- WISCONSIN POINT
- YMCA BLDING
- YMCA SPECIAL USE

railroads

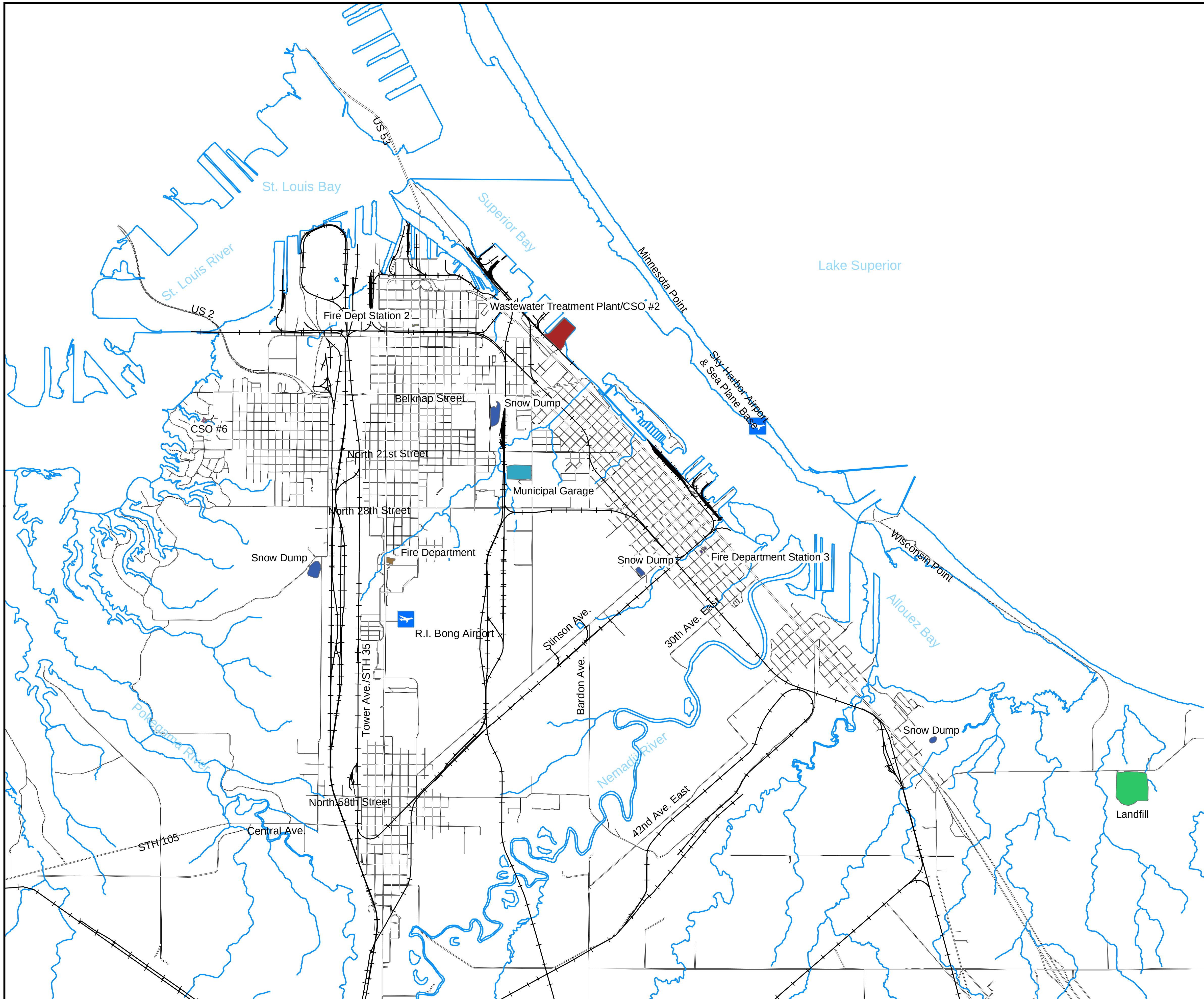
Streets

0 0.5 1 2 Miles

Date: 2/17/2015

THE CITY OF
SUPERIOR
WISCONSIN
Living up to our name.

Figure 2.8.7
Municipal Garages, Storage Areas, and other Public Works Facilities



Legend

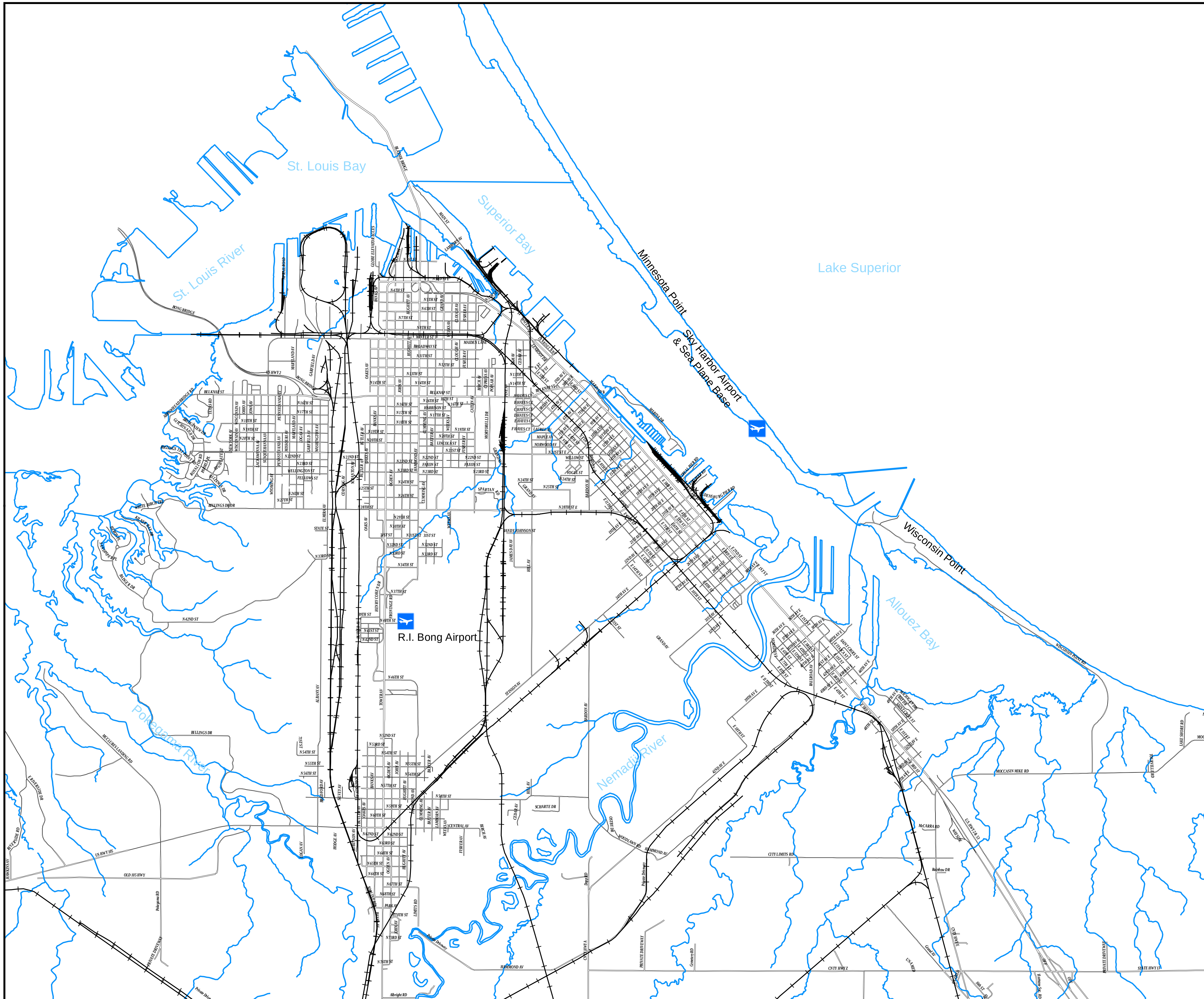
Municipally_Owned_Facilities

Facility

- CSO #6
- Fire Department
- Fire Department Station 2
- Fire Department Station 3
- Landfill
- Municipal garage
- Snow Dump
- Wastewater Treatment Plant/CSO #2
- railroads
- Streets

0 0.5 1 2 Miles

Date: 2/17/2015



THE CITY OF SUPERIOR WISCONSIN

Living up to our name.

Figure 2.8.8
Streets

Legend

railroads

Streets

0 0.5 1 2 Miles

Date: 2/17/2015

CHAPTER I – EXECUTIVE SUMMARY

This study has been performed in conjunction with and/or for the benefit of the City of Superior, the University of Wisconsin, the Soo Line Railroad, and the general public.

In June 2012, approximately 8-10 inches of rain fell on the City of Superior. Widespread surface and basement flooding ensued. Faxon Creek, which drains approximately 3,500 acres through a 10-foot brick sewer that discharges to the Bay of Superior, overtopped its banks. Faxon Creek interceptor, a sanitary sewer artery, parallels much of the creek. The high creek levels overtopped several roadways and submerged sanitary manholes along the Faxon Creek interceptor. Water from the creek found its way into the basements of many homes that drain into the interceptor. On August 2, 2012 President Obama declared a major disaster (DR-4076) for the counties of Ashland, Bayfield, and Douglas and the Red Cliff Band of Lake Superior Chippewa.

This study has evaluated a series of potential improvement scenarios to identify the most cost-effective alternative to lowering the base flood elevation of the creek thereby mitigating the risk of basement flooding. To do so, a model of the Faxon Creek watershed was developed to evaluate a range of potential conveyance and stormwater detention alternatives and the corresponding reduction in flood risk each provides. These risks were compared to corresponding estimates of improvement costs to assess the cost-effectiveness of each combination of system improvements.

Increasing the creek's hydraulic capacity to maximize the conveyance of stormwater to Central Park and through the K-Street sewer to the Bay of Superior was found to be most cost-effective at reducing the risk of flooding. K-Street sewer is structurally unsound and must be repaired. Major repairs completed in 2014 will stop the deterioration of the sewer while increasing its capacity by 30%.

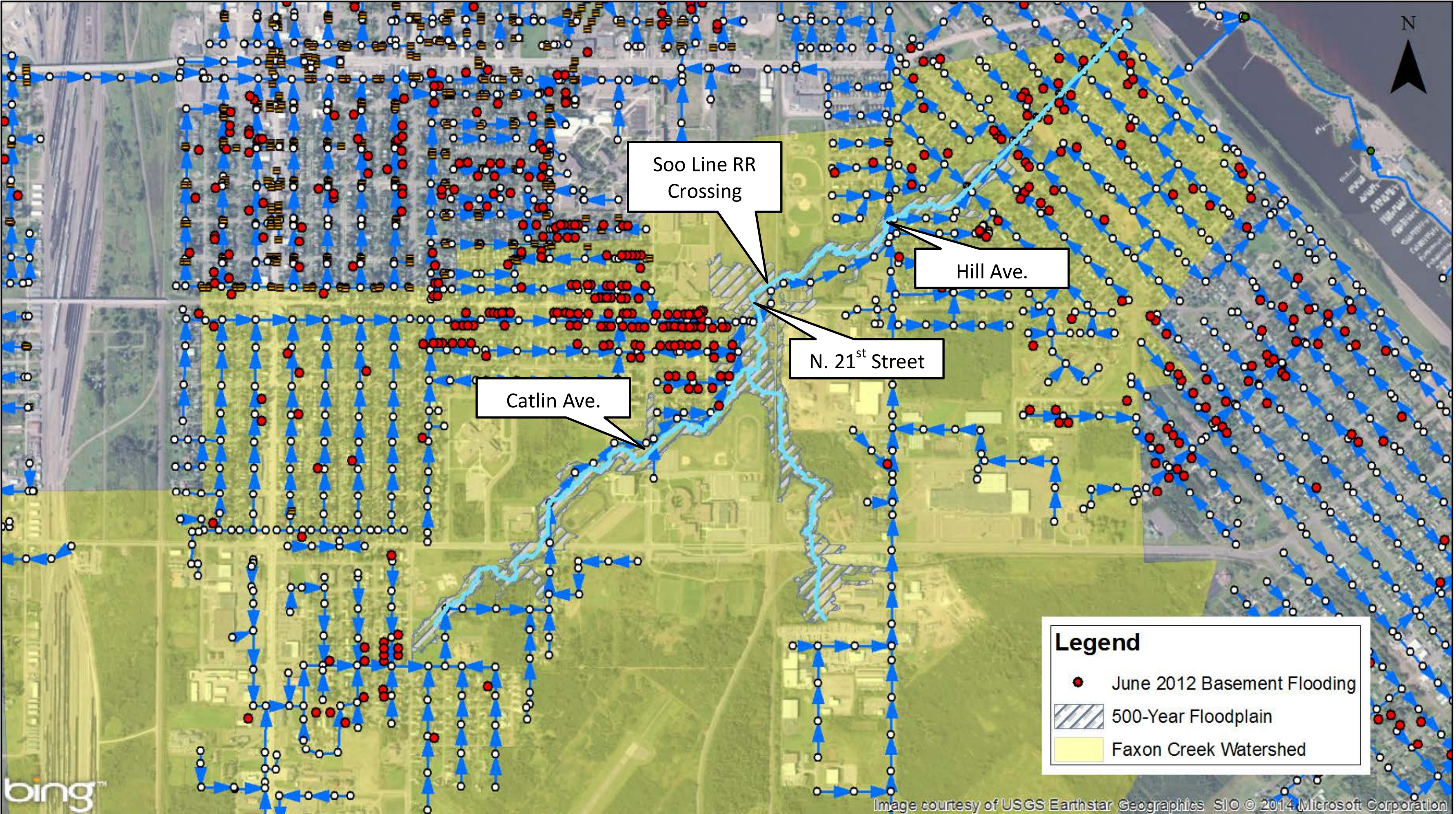
It should be noted that the City has already completed several improvements to the K-Street sewer including replacing the most downstream section of the sewer with a smooth coated CMP, extending the sewer past Marina Drive, and replacing the culverts under the Osaugie Trail.

In addition, by improving the crossings at Hill Avenue, Soo Line Railroad, North 21st Street, and Catlin Avenue, the risk of widespread flooding could be reduced to a 1% chance of occurrence in any given year at a cost of approximately $2,300,000. However improving the Soo Line crossing may prove challenging as it is on railroad property.

Other alternatives were analyzed, but rejected. These included less cost-effective options that might mitigate the need for all four crossings by constructing detention ponds at Heritage Park, on property owned by the University of Wisconsin, and property adjacent to and owned by the Soo Line railroad. However detention can only eliminate the need for the N 21st Street crossing. For example, a pond at the Heritage Park site would eliminate the need for this crossing while reducing the risk of flooding to a 1% annual probability of occurrence at a total cost of $4.7M. This pond could also provide TSS reduction. The Soo Line pond could reduce the risk of flooding to 0.75% per year at a total cost of $5M, but would not provide TSS reduction.

Since the Hill Avenue and Soo Line Raiload crossings are the furthest downstream and need to be improved under all scenarios, these should receive top priority. The N 21st Street culvert is the next upstream structure that warrants improvement, however this need could be negated by detention at

Heritage Park and/or the University of Wisconsin, albeit at a much higher total cost. The arch culvert under the old Grand Ave alignment south of N 21st is no longer needed and should be removed. While the Catlin Avenue crossing needs to be improved regardless, it should not be improved until all downstream improvements are complete.



N
Soo Line RR Crossing
Hill Ave.
N. 21st Street
Catlin Ave.
Legend
June 2012 Basement Flooding
500-Year Floodplain
Faxon Creek Watershed
bing
Image courtesy of USGS Earthstar Geographics SIO © 2014 Microsoft Corporation