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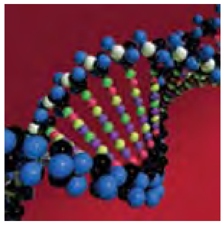
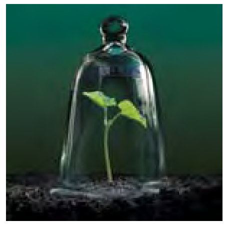

CURRENT CONDITIONS REPORT FOR THE SAGINAW RIVER, FLOODPLAIN, AND BAY

Prepared for
THE DOW CHEMICAL COMPANY

Prepared by
ENVIRON

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FIGURES

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ACRONYMS / ABBREVIATIONS

%	percent
°F	degrees Fahrenheit
ACOE	Army Corps of Engineers
AOC	Area of Concern
AST	above ground storage tank
ASTM	American Society for Testing and Materials
bgs	below ground surface
CCR	Current Conditions Report
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CERCLIS	Comprehensive Environmental Response Compensation and Liability Information System
cfs	cubic feet per second
cm	centimeter
CORRACTS	Corrective Action
CSO	combined sewer overflow
DDT	dichlorodiphenyltrichloroethane
DOT OPS	Department of Transportation, Office of Pipeline Safety
dw	dry weight
EDR	Environmental Data Resources, Inc.
EFDC	Environmental Fluid Dynamics Code
EPCRA	Emergency Planning and Community Right to Know Act
ERNS	Emergency Response Notification System
FCMP	Fish Contaminant Monitoring Program
FEMA	Federal Emergency Management Agency
ft	feet or foot
GAO	Government Accounting Office
GLNPO	Great Lakes National Program Office
GLWQA	Great Lakes Water Quality Agreement
GM	General Motors
HMIRS	Hazardous Materials Incident Report System
HUC	Hydrologic Unit Code
IJC	International Joint Commission
in	inches
kg/m^3	kilograms per cubic meter
LSR-BC	Lower Saginaw River (Bay County)
LSR-SC	Lower Saginaw River (Saginaw County)
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MG	million gallons
MGD	million gallons per day

mg/kg	milligram per kilogram
mg/L	milligram per liter
MGP	manufactured gas plant
mm	millimeter
MNFI	Michigan Natural Features Inventory
MSL	mean sea level
n	sample size
ng/kg	nanogram per kilogram
ng/L	nanogram per liter
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NWI	National Wetland Inventory
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCDD/Fs	dioxins and furans
PEAS	Pollution Emergency Alerting System
ppt	parts per trillion
RAATS	RCRA Administration Action Tracking System
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
RTB	retention/treatment basins
SB	Saginaw Bay
sq mi	square mile
SSURGO	Soil Survey Geographic
SVOC	semivolatile organic compound
TCDD	tetrachlorodibenzo-*p*-dioxin
TCDF	tetrachlorodibenzofuran
TEF	toxic equivalency factor
TEQ	toxic equivalent
TOC	total organic carbon
TRI	Toxic Release Inventory
TSS	total suspended solids
µg/L	microgram per liter
µm	micrometer
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USR	Upper Saginaw River
UST	underground storage tanks
VOC	volatile organic compound
WHO	World Health Organization
ww	wet weight
WWTP	wastewater treatment plant

1. INTRODUCTION

This Current Conditions Report (CCR) for the Saginaw River, the 100-year floodplain, and Saginaw Bay summarizes environmental information relevant to establishing the scope of future investigations, including a description of the physical characteristics of the river, floodplain, and bay, a summary of the potential historical sources of hazardous substances, a preliminary assessment of media in the river that may have been impacted by releases of hazardous substances, and discussion of current data gaps.

The geographic focus of this CCR – the study area – is the Saginaw River and its 100-year floodplain, as well as Saginaw Bay (SB). The most recent flooding corresponding to an approximate 100-year event occurred in September 1986. The areas along the Saginaw River that were inundated because the river overtopped the riverbanks during the 1986 event have not been accurately delineated. Therefore, the Federal Emergency Management Agency's (FEMA) 100-year flood delineation is used in this CCR to represent the 100-year floodplain. The FEMA floodplain is believed to overestimate the true extent of a 100-year flood, as it does not fully account for levees and other flood protection measures put in place to limit flooding from a 100-year precipitation event. Ongoing investigations of the Saginaw River are expected to aid in the accurate delineation of the floodplain.

As illustrated in Figure 1-1, for purposes of this CCR, the Saginaw River is divided into three reaches, to facilitate presentation, mapping, and discussion. As defined in this CCR, the first reach – the Upper Saginaw River or USR – extends from the confluence with the Tittabawassee River to (but not including) the Sixth Street Turning Basin, a distance of approximately five river miles. As defined in this CCR, the second reach – the Lower Saginaw River in Saginaw County or LSR-SC – extends from the Sixth Street Turning Basin to the Saginaw County-Bay County boundary, a distance of approximately six river miles. As defined in this CCR, the third reach – the Lower Saginaw River in Bay County or LSR-BC – extends from the Saginaw County-Bay County boundary to the mouth of the river at Saginaw Bay, a distance of approximately 11 river miles.[1]

Consistent with the boundary of the Saginaw Bay Watershed Area of Concern (AOC) (Brandon et al. 1991) and as illustrated in Figure 1-1, Saginaw Bay extends from the shoreline to the imaginary line drawn between Au Sable Point and Point Aux Barques. The inner bay and

[1] The boundary between USR and LSR-SC used in this CCR differs from that used by the U.S. Army Corps of Engineers (ACOE). ACOE defines the Upper Saginaw River as extending from the confluence of the Tittabawassee and Shiawassee Rivers to just upstream of Bay City. ACOE defines the Lower Saginaw River as extending from that just upstream of Bay City to the mouth of the river.

outer bay are also differentiated by an imaginary line drawn between Point Lookout and Sand Point (MDNR 1986). In addition to the river and bay, upland portions of the Saginaw Bay watershed are also discussed in some sections of this CCR, insofar as upland resources influence conditions in the river and bay. However, the predominant focus of this CCR is the Saginaw River, its 100-year floodplain, and Saginaw Bay.

The CCR is organized as follows: Section 2 (Study Area Background) describes the Saginaw River and Bay's geology, hydrogeology, hydrology, geomorphology, topography, soils, sediment, climate, land development, water body use, demographics, and ecology. Section 3 (Scale and Effects of Anthropogenic Activities) describes major anthropogenic activities that have influenced and continue to influence the river and bay, such as navigational dredging, eutrophication, soil erosion and sedimentation, combined sewer overflows (CSOs), municipal wastewater treatment plants (WWTPs), landfills, and various sources of chemical loading. Section 4 (Summary of Environmental Data) describes previous investigations conducted on the river and bay, and generally characterizes the nature and extent of contamination of soil, sediment, surface water and biota of USR, LSR-SC, LSR-BC, and SB. Finally, Section 5 summarizes conclusions from the 2007 State of the Great Lakes report (USEPA and Environment Canada 2007) related to the general status and trends of environmental conditions in Saginaw Bay, Lake Huron, and throughout the Great Lakes. References are presented in Section 6. A photographic log of the Saginaw River is provided in Appendix A and the comprehensive list of documents and websites reviewed during the compilation of this CCR, is provided in Appendix B.

2. BACKGROUND

This section provides an overview of the study area. The overall goal of this section is to provide a common understanding of the full range of physical, biological, and societal features of the study area. As such, this section describes the study area setting, with respect to the many characteristics that influence the fate, transport, and effects of chemicals in the river, floodplain, and bay, as well as its future recovery. Aerial photographs of USR, LSR-SC, and LSR-BC are provided in Figures 2-1a, 2-1b, and 2-1c, respectively.

The study area is located within the Saginaw River and Bay watershed (Figure 2-2). The Saginaw River is formed by the confluence of the Tittabawassee River and the Shiawassee River just south of Saginaw, Michigan. From the confluence of the Tittabawassee and Shiawassee Rivers, the Saginaw River flows north for 22.3 miles through the cities of Saginaw, Zilwaukee, Bay City, and Essexville. The river flows through Saginaw County and Bay County.

Saginaw Bay is a southwestern extension of Lake Huron, located in the east central portion of Michigan's Lower Peninsula. Several islands are located within Saginaw Bay, including the Charities, North, Heisterman, and Maisou Islands located southwest of Sand Point, as well as Defoe, Pitcher, and Lonetree Islands towards Fish Point. The surface area of the bay is 1,143 square miles (sq mi). The average depth of the bay is 29.2 feet (ft),[2] while the maximum depth is 132.9 ft (Beeton et al. 1967 as cited by Hendrix and Yocum 1984). The average depth of the inner bay is 16.7 ft, while the average depth of the outer bay is 44.9 ft.[3] The bay is 52 miles long and varies in width from 13 miles to 26 miles. Circulation in Saginaw Bay is counterclockwise.

2.1 Geology

Glacial deposits constitute the unconsolidated overburden material at the ground surface in the region of the Saginaw River channels and floodplains. At the maximum extent of the Wisconsinan Glaciation approximately 18,000 years ago, a massive ice sheet (glacier) covered the study area and vicinity. As the glacier retreated, the thinning ice came under the influence of a major lobe following the axes of Saginaw Bay, until the area was free of ice approximately 12,000 years ago. As the glacier advanced, soil and rock was eroded from the ground surface and integrated with the ice sheet, which was subsequently redistributed by deposition as the glacier melted and retreated. These glacial sediments constitute 50 ft to 200 ft of unconsolidated overburden material in the study area and vicinity that were deposited during Pleistocene Epoch

[2] ftp://ftp.glerl.noaa.gov/publications/tech-reports/gerl-115/tm-115.pdf,
[3] ftp://ftp.glerl.noaa.gov/publications/tech-reports/gerl-115/tm-115.pdf.

glaciation events as a result of the ice sheet advancements and retreats across the region (Olcott 1992). This material in the study area and vicinity generally consists of glaciofluvial (meltwater) deposits (such as outwash, kames, and eskers) and is generally sorted, stratified deposits of sand or sand and gravel mixtures.

After the final glacial advance, meltwater ponded at the edge of the retreating ice, forming ice marginal lakes. Large lakes formed in areas where the land was depressed from the weight of the glacier or where the glaciers blocked natural drainage patterns. Near-shore sand layers and small dunes were deposited on top of the lacustrine (lake) bottom clay-rich sediments as the shorelines retreated (Dow 2002). These lake bed clay and sand layers form the primary surficial deposits in the Saginaw River and floodplain. Saginaw Bay is a shallow-water remnant of Pleistocene Lake Saginaw. Saginaw Bay sediments range from clay to large pebbles, with fine to medium grained quartz sand being common.

Pennsylvanian sedimentary bedrock, the Saginaw Formation, underlies the unconsolidated, quaternary glacial deposits in the study area and vicinity. These Pennsylvanian rocks consist of fine grained sandstone and siltstone with inter-bedded shale, limestone, coal, and gypsum in the Saginaw Bay area (Olcott 1992). The sedimentary petrogenesis of the Saginaw Formation was likely a mixed marginal marine/deltaic environment. The Saginaw Formation is extensively eroded due to glaciation and varies in thickness, ranging from very thin to 700 ft, but typically is less than 300 ft (Olcott 1992). The Saginaw Formation is overlain in areas by the youngest bedrock of the Michigan basin, the Jurassic "Red Beds," which generally consist of red shale, gypsum, and sandstone, ranging in thickness from very thin to 300 ft (Olcott 1992).

A bedrock geology map of the study area and vicinity is included as Figure 2-3a and a quaternary geology map of the study area and vicinity is included as Figure 2-3b.

2.2 Hydrogeology

Groundwater is first encountered in the surficial aquifer system in the study area and vicinity. The surficial aquifer system is the most widespread aquifer system in the region. In the study area and vicinity, the surficial aquifer system includes glaciofluvial deposits, which can range from 50 ft to 200 ft thick (Olcott 1992). These permeable formations of sand and/or sand and gravel mixtures are exposed at the land surface and readily receive, store, transmit, and discharge water. The surficial aquifer system is a primary source of water in the region and provides much of the base-flow to streams. Recharge to the surficial aquifer is typically through direct precipitation: rain infiltration in the warm season and snow melt in cold season.

Below the surficial aquifer system is the Pennsylvanian aquifer, referred to as the Grand River-Saginaw aquifer in the study area and vicinity, a major producing aquifer in the region. This Pennsylvanian aquifer is situated in the central portion of Michigan's Lower Peninsula and is utilized as a major domestic, municipal, and industrial water supply (Olcott 1992). This aquifer is made up of Pennsylvanian rocks of the Grand River and Saginaw Formations. The aquifer consists primarily of sandstone with lesser amounts of inter-bedded shale. These formations are overlain by Jurassic "Red Beds" that act as a confining unit between the Pennsylvanian aquifer and the surficial aquifer. The major source of recharge for the Pennsylvanian aquifer exists where the Grand River and Saginaw Formations outcrop below the surficial aquifer (Olcott 1992).

Groundwater flow in the surficial aquifer system in the study area and vicinity is generally a function of the local topography and, therefore, is typically a subdued reflection of that topography. As illustrated in Figure 2-4, groundwater in the Pennsylvanian aquifer in the study area and vicinity generally flows toward the Saginaw River and ultimately towards Saginaw Bay. Depth to groundwater in the Saginaw Formation (Pennsylvanian aquifer) in Saginaw County has ranged from 8.85 ft to 12.82 ft in the past 6.5 years.[4]

The groundwater resources in the watershed do not provide an adequate source of municipal drinking water for several of the larger communities. As is indicated in the 2005 Groundwater Inventory for Michigan (MDEQ 2005a), groundwater resources in the Saginaw River region yield an insufficient quantity of water to serve as a municipal drinking water source. In addition, the bedrock aquifer has elevated concentrations of dissolved solids due to the local geology rendering it unusable as a drinking water source (MDEQ 2005a). Therefore, the cities of Midland, Saginaw, Zilwaukee, Bay City, and Essexville and nearby townships rely on Saginaw Bay and Lake Huron for drinking water (Section 2.10).

2.3 Hydrology

The Saginaw Bay watershed is the largest of Michigan's watersheds, draining 8,709 sq mi of land (Figure 2-2) or 15 percent (%) of the total land area of the state of Michigan (Arthur et al. 1996). The Saginaw River basin (Hydrologic Unit Code [HUC] 040802) is the largest subbasin draining into the bay covering an area of 6,160 sq mi or 71% of the area draining into Saginaw Bay. The Saginaw subbasin contains the following six United States Geological Survey (USGS) 8th code HUCs:

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[4] http://nwis.waterdata.usgs.gov/mi/nwis/gwlevels?site_no=431457084194401&agency_cd=USGS&format=gif.

1. 04080201 Tittabawassee: 1430 sq. mi (23% of the Saginaw subbasin)
2. 04080202 Pine: 1040 sq mi (17% of the Saginaw subbasin)
3. 04080203 Shiawassee: 1220 sq mi (20% of the Saginaw subbasin)
4. 04080204 Flint: 1340 sq mi (21% of the Sagniaw subbasin)
5. 04080205 Cass: 881 sq mi (14% of the Saginaw subbasin)
6. 04080206 Saginaw: 250 sq mi (4% of the Saginaw subbasin)

The Saginaw River HUCs drain directly into Saginaw Bay. The following three USGS 8th code HUCs are the smaller watersheds that flow directly into Saginaw Bay:

1. 04080101 Au Gres-Rifle: Area is 1030 sq mi
2. 04080102 Kawkawlin-Pine: Area is 503 sq mi
3. 04080103 Pigeon-Wiscoggin: Area is 853 sq mi

On average, 39% of the flow in the main Saginaw River is contributed by the Tittabawassee River, 11% by the Shiawassee River, 20% by the Flint River, 14% by the Cass River, and 16% by other sources. The Flint and Cass Rivers are tributaries to the Shiawassee River. They flow into the Shiawassee River approximately six miles and one mile (respectively) upstream of the confluence of the Tittabawassee and Shiawassee Rivers. Average discharge rates for rivers within the Saginaw Bay watershed are: Saginaw (4,061 cubic feet per second or cfs), Tittabawassee (1,695 cfs), Flint (742 cfs), Cass (494 cfs), Chippewa (424 cfs), Shiawassee (424 cfs), and Pine (318 cfs) (Brandon et al. 1991 as cited by Arthur et al.1996).

The Saginaw River is slow-flowing most of the time, but has very high flow rates for very short periods (Cardenas et al. 1995). Flows in the Saginaw River are driven by a combination of upstream tributary flows and by seiche-related water level fluctuations on Saginaw Bay (i.e., oscillations in water surface elevations caused by meteorological events). Historic flood records are listed in Table 2-1. The maximum flood elevation occurred in 1904 and flooding of almost the same magnitude occurred in 1986. The 1986 flood was estimated to be a 100-year event. It occurred in September following rainfall of up to 12 inches (in) (30 centimeters [cm]) over 36 hours in some areas of the watershed, followed by another 3 in to 7 in (8 cm to 18 cm) of rainfall. Cardenas et al. (1995) report calculated flow rates for the lower Saginaw River based on data from 1940 to 1990 as follows:

- Maximum = 68,157 cfs
- Minimum = 247 cfs
- 10-year flood = 53,926 cfs

- 5-year flood = 49,546 cfs
- 2-year flood = 42,766 cfs
- 1-year flood = 34,679 cfs
- Median = 2,013 cfs

There is a USGS flow monitoring station in Saginaw, MI (USGS 04157000) with monthly flow data for the years 1992 through 2005. The average flow over this time period for each month (with data) is plotted in Figure 2-5. This hydrograph shows a pattern of high spring flows between 6000 cfs and 9000 cfs, occurring during the spring run-off period from February to May and low summer flows of about 2000 cfs from July to October.

The hydrograph and drainage patterns in the Saginaw River watershed are modified from their natural state, due to a combination of agriculture and municipal land uses, as well as water transfers from Lake Huron. Agricultural activities in the watershed rely on water conveyance systems such as drains, ditches, and field tiles, which have altered wetland retention capacity. Urban areas with extensive impermeable surfaces reduce the amount of water that is absorbed and increase the volume of runoff from storm events. No analyses of predicted changes in Saginaw River peak flows due to these activities were identified during the literature search and evaluation conducted for this CCR.

Although the Saginaw River itself is free-flowing, dams upstream of the confluence of the Shiawassee and Tittabawassee Rivers influence the hydrograph and stream flows of the Saginaw River. Approximately 315 dams are located in the Saginaw River watershed, serving a variety of purposes including flood storage, recreation, power generation, sediment retention, and water supply (PSC 2005). Dams are located on the Tittabawassee River at Secord, Smallwood, Edenville, Sanford, and Midland. Tittabawassee River flow and water level fluctuate daily in response to releases from the Sanford Dam (ATS 2006). No quantitative analyses of the impacts of upstream dam operation on Saginaw River flow or water level were identified.

Figures 2-1a through 2-1c illustrate the extent of the 100-year floodplain, as mapped by FEMA. The FEMA map, however, does not distinguish flooding that results from water overtopping the river banks versus water that accumulates in between lands adjacent to the river because precipitation exceeded infiltration. As is evident from that map, within the USR, the floodplain is constricted through engineering controls and urban development associated with the city of Saginaw. In the LSR-SC, the floodplain broadens considerably, encompassing extensive wetlands and agricultural areas. In the vicinity of Bay City in the LSR-BC, the floodplain again narrows through engineering controls and urban development, except along the immediate shoreline of Saginaw Bay. The environmental implications of the constructed alterations to the channel and floodplain are further discussed in Section 3.2.

Circulation in Saginaw Bay is driven by flow from the Saginaw River, which provides about 90% of the hydraulic load to the bay (Beeton et al. 1967 as cited by Hendrix and Yocum 1984), as well as by the direction and velocity of the wind (Limno-Tech, Inc. 1983 as cited by Hendrix and Yocum 1984). Under the prevailing west-southwesterly wind, the circulation in the bay is counterclockwise, with water from Lake Huron entering the bay along the northern shore and bay water moving along the southern shore back to Lake Huron. The retention time of the bay is 52 days (Dolan 1975 as cited by Hendrix and Yocum 1984).

Saginaw Bay water surface elevations and seiche effects can affect Saginaw River water levels and flow rates for its entire length (ATS 2006). Within a few hours, a northeasterly gale driving water into the bay can raise the water level at the mouth of Saginaw River by 3 ft to 4 ft. A southwesterly wind sometimes lowers the level sufficiently to cause large vessels to ground in the channel (NOAA 2007). In general, fluctuations in water levels occur over three temporal scales: 1) short-term fluctuations (seiche) in water level caused by persistent winds and/or differences in barometric pressure; 2) seasonal fluctuations reflecting the annual hydrologic cycle in the Great Lakes basin; and 3) inter-annual fluctuations in lake level as a result of variable precipitation and evaporation within their drainage basins (Minc 1997, Minc and Albert 1998).

2.4 Geomorphology and Interaction of the Floodplain and River

The Saginaw River and floodplain are part of a dynamic interrelated fluvial system. Soils present in the floodplain were deposited by the ancestral and current river and are being constantly reworked. Although portions of the Saginaw River – such as those reaches that flow through the cities of Saginaw and Bay City – are channelized and otherwise engineered, the middle reach (LSR-SC) displays some characteristics of a meandering stream type of fluvial system. Meanders within the LSR-SC are generally less pronounced than in some river systems, but some features of a meandering system are present.

Meandering stream systems are characterized by a sinuous river system that meanders across a river valley. Erosion and deposition are the primary processes that operate in the river/floodplain system. These processes occur constantly and simultaneously in active fluvial systems, although the relative rates are both temporally and spatially variable. Erosion may dominate in some areas (particularly along the outer cut banks of meanders), while deposition will dominate elsewhere (particularly along the inner point bars of meanders). The general locations of these processes are predictable and identifiable by the geomorphologic features that they create, such as levees, cut banks, point bars, overbank areas, and crevasse splays.

Human activities have disrupted the natural fluvial system through the construction of various structures and the creation of cut and fill areas. These features divert river flow, restricting erosion and deposition in some areas, while increasing erosion or deposition elsewhere. Examples of constructed features that affect the river system include elevated roadways and railroads, where fill is used to build them up above the floodplain, fill areas used to elevate the land surface above the floodplain, erosion control features used to stabilize river banks, dams, and cut areas where floodplain materials were excavated.

Sediment transport processes and related rates of sediment bed erosion and deposition on the Saginaw River have not been well characterized to date. Rates of sediment transport and bed erosion or deposition rates are expected to be dependent on a number of factors, including river flow rate, river depth, river geomorphology, and the load of sediment delivered from upstream tributaries.

Specific measurements of erosion and deposition have not been made on the Saginaw River, nor has mapping of geomorphological features of the floodplain. However, Cardenas et al. (1995) modeled sediment deposition and transport within the LSR-BC, focusing on the effects of scour and deposition on the river's bathymetry.

The USR is a relatively low energy reach, with a channel that ranges in width from 400 ft to 1,650 ft. The USR channel water depths range from 0.1 ft on the shoreline to 22 ft in the center of the channel upstream of the I-675 bridge. The channel of the USR is relatively straight, with most of its banks between the confluence of the Shiawassee and Tittabawassee Rivers and the Sixth Street Turning Basin armored with various types of riprap, gabions, and sheetpiling. The river channel of the USR is slightly sinuous at the southern (upstream) end and relatively straight in the northern (downstream) portion. There are a number of adjoining constructed basins and slips within the study area.

The only geomorphological information identified for LSR was a modeling exercise published by Cardenas et al. (1995), which focused on in-stream sediment and bedload transport, erosion, and deposition. During and after peak spring runoff, Cardenas et al. (1995) predicted that re-suspension occurs in the channel and that deposition occurs in the nearshore areas. Large amounts of re-suspension were predicted to occur in the middle of the narrow parts of the river, while deposition was predicted to be highest (although relatively small) in a small number of nearshore areas mostly in the downstream part of the river.

2.5 Topography and Bathymetry

As illustrated in Figure 2-6, the topography within the Saginaw River floodplain is relatively flat, with elevational changes not exceeding 20 ft. The minimum land elevation occurs at the soil-water interface of the Saginaw River and Saginaw Bay (580 ft above mean sea level or MSL), while the maximum land elevation occurs at the western most extent of the Saginaw River 100-year floodplain, approximately 8.5 miles west of RM9 (630 ft above MSL).

The bathymetry of Saginaw Bay is illustrated in Figure 2-7. The inner bay is relatively shallow with a mean depth of 5 ft. The outer bay is somewhat deeper, with approximate mean and maximum depths of 15 ft and 35 ft, respectively (Johengen et al. 2000).

2.6 Soils

Soil maps for the Saginaw River floodplain are presented in Figures 2-8a through 2-8c for the USR, LSR-SC, and LSR-BC, respectively. The soils in the vicinity of the Saginaw River floodplain are of variable composition related to the influences of glacial and post-glacial fluvial processes. Within the broader geographical scale of the Saginaw Bay watershed, Arthur et al. (1996) describes soils in the lake plain as loam to clay soils, with sandy soils in the outwash plains and channels. The surface soils over large areas to the east, south, and southwest of Saginaw Bay are rich in clay, relatively impermeable, and, in their native state, poorly drained and erodable. Such soils have low water capacity and reach saturation quickly, generating runoff faster and in greater volumes (MDNR 1988). Annual soil erosion has been estimated at 6.1 million tons from wind and 3.6 million tons from sheet and rill sources (Arthur et al. 1996). The west coastal subbasin has rolling plains, coarse textured soils, and higher percentages of forested land (Arthur et al. 1996); as such, they are less susceptible to erosion than those of the lake plain.

Soil types in the Saginaw River area were determined from the United States Department of Agriculture (USDA), Natural Resources Conservation Service Soil Survey Geographic (SSURGO) database.[5]

Generally, the surface soils of the Saginaw River area are loamy and fine-grained, with a

5 http://www.dnr.state.mi.us/spatialdatalibrary/sdl/Soils/SSURGO/SAGINAW_ssurgo_24k.exe (Saginaw County) and http://www.dnr.state.mi.us/spatialdatalibrary/sdl/Soils/SSURGO/BAY_ssurgo_24k.exe (Bay County).

clay content ranging from 15% to 30% in the soil profile. Most floodplain soils are hydric, indicating they are poorly or very poorly drained and experience ponding or flooding during the growing season. A large portion of land in the vicinity of the Saginaw River floodplain is urban; in such areas, identification of native soils is not feasible. Specific soils surrounding the USR, LSR-SC, and LSR-BC are discussed in greater detail below.

2.6.1 Upper Saginaw River Floodplain Soils

The SSURGO database delineates soils within the USR floodplain into a number of different units. Udorthents soils make up the largest proportion, approximately 29%, of the total USR floodplain. Udorthents soils are loamy and found on nearly all slopes. Udorthents soils have been disturbed by human activity and are typically located in areas where the original soil material has been cut away and filled with a loamy material. Thus, Udorthents soils can represent several different soil types or be composed of one soil from an adjacent cut. Udorthents soils dominate the northwestern side of the Saginaw River near RM21, as well as on both sides of the river near the Sixth Street Turning Basins (i.e., the boundary between the USR and LSR-BC).

The Sloan-Ceresco complex (frequently flooded) and Tappan loam each comprises an additional 12% of the total USR floodplain area. The Sloan-Ceresco complex is a combination of Sloan and Ceresco soils. Sloan soil is silt loam in the surface 2 ft and clay loam, silty clay loam, or silt loam to a depth of 42 in below ground surface (bgs). From 42 in bgs to bedrock, a very fine sandy loam is present in this complex. Ceresco soil is also silt loam in the surface 19 in and fine sandy loam at depth. The Sloan-Ceresco complex is considered hydric soil, due to its taxonomic classification and its shallow water table during the growing season. Sloan soil is in the hydrologic group B/D, indicating a wet soil that can be adequately drained. Ceresco soil is in the hydrologic group B. The Sloan-Ceresco complex (frequently flooded) is primarily located on the eastern side of the Saginaw River, between RM22 and RM20. Tappan loam soils are defined by loam in the surface 12 in and clay loam or silty clay loam at depth. As a result of their taxonomic classification and frequent ponding for a long or very long duration during the growing season, Tappan loam soils are hydric. Tappan loam is found in the far southeastern portion of the USR floodplain, between RM21 and RM22.

Other common soil types in the USR floodplain are the Zilwaukee-Misteguay complex (rarely flooded) and urban land. The Zilwaukee-Misteguay complex is silty clay at surface soil and silty clay to silty clay loam at depth. This soil unit is also considered hydric due to its taxonomic classification and shallow water table during the growing season. These soils have a high percentage of clay throughout the soil profile, ranging from 35% to 60%. Urban land is covered by streets, parking lots, buildings, or other impervious structures that preclude identification of the soil series. Thus, urban land denotes soils that are not classifiable. Urban land comprises approximately 9% of the USR floodplain.

2.6.2 Lower Saginaw River (Saginaw County) Floodplain Soils

Twenty-five different soil types comprise the LSR-SC floodplain, although Tappan loam makes up nearly 42% of the total area. As described above, Tappan loam is loam within the top foot and clay loam or silty clay loam at depth. These poorly drained soils have frequent ponding and are in a hydrologic group of B/D, indicating the potential for runoff. Tappan loam is distributed between the far eastern and western edges of the LSR-SC floodplain.

Sloan silt loam makes up 14% of the total area of the LSR-SC floodplain and is classified as silt loam to a depth of 24 in bgs and clay loam, silty clay loam or silt loam from 24 in to 42 in bgs. From 42 in bgs to bedrock, very fine sandy loam is present. These soils are not typically flooded; however, they are considered hydric soils due to their taxonomic classification and the combination of a shallow water table during the growing season and a low permeability. Sloan silt loam is composed of 15% to 35% clay at all depths and 2% to 6% organic matter at the surface. Sloan silt loam is located east and west of the Saginaw River between RM13 and RM11.

Prevalent in the vicinity of the USR, as well as the LSR-SC, Udorthents soils indicate disturbed land due to human activities. In the vicinity of the LSR-SC, Udorthents soils are located immediately adjacent to the Saginaw River between RM16 and RM13, as well as along Interstate Route 75. These soils comprise approximately 9% of the LSR-SC floodplain area. Also comprising 9% of the LSR-SC floodplain are Fluvaquents soils. These hydric soils are frequently flooded over long or very long durations. Fluvaquents soils are poorly to very poorly drained and may have a water table at or near the soil surface. The Fluvaquents soils are located along the Saginaw River near RM13.

2.6.3 Lower Saginaw River (Bay County) Floodplain Soils

Much like the LSR-SC, soil within the floodplain of the LSR-BC is dominated by loam. At 40% of the LSR-BC floodplain, Tappan loam is found mainly on the eastern and western edges of the floodplain between RM10 and RM8 and again between RM2 and RM1. Sloan loam comprises approximately 13% of the LSR-BC floodplain. Sloan loam is loam to 11 in bgs, and clay loam, silty clay loam, or silt loam at depth. As with the majority of floodplain soils, Sloan loam is a hydric soil because it is poorly or very poorly drained and has a shallow water table. Sloan loam is classified in the hydrologic group B/D.

The Aquents soils (sandy and loamy) comprise approximately 12% of LSR-BC floodplain soil. The Aquents soils are poorly drained hydric soils, which lack distinct soil horizons. The Aquents soils are located immediately adjacent to the Saginaw River from RM8 to the confluence at the Saginaw Bay. Cohoctah loamy fine sand, Belleville loamy sand, and Londo loam comprise 10%, 6%, and 5% of the LSR-BC floodplain, respectively. Cohoctah loamy fine sand is a hydric soil because it is poorly or very poorly drained and it experiences frequent flooding for long or very long durations. Cohoctah soil is loamy fine sand to 11 in bgs and fine sandy loam, loam, or sandy loam at depth. It is wet soil that can be adequately drained, putting it in the dual hydrologic group B/D. The majority of Cohoctah loamy fine sand is located near the Saginaw River between RM10 and RM7. Like Cohoctah soil, Belleville soil is loamy sand in the surface soil, fine sand or loamy fine sand to 36 in bgs, and clay loam or loam to bedrock. Belleville loamy sand is a hydric soil and is classified in the hydrologic group B/D. Londo loam is loam to 7 in bgs and clay loam in the subsurface soil. Londo loam is also a hydric soil and experiences frequent ponding for long or very long durations. Londo loam is located in the far western reaches of the LSR-BC floodplain near RM7 and RM8.

2.7 Sediment

The Saginaw River is sediment-enriched, in that siltation and soil erosion are linked to several of the identified impairments of the AOC (PSC 2002, Saginaw Bay NWI 1994), as further detailed in Section 3.6. Current understanding of sediment depth, organic carbon content, and grain size within the river is provided by three investigations: 1) ACOE's 1999 sediment sampling from the LSR-SC, LSR-BC, and SB; 2) CH2MHill's (2005) preliminary sediment investigation in the USR; and 3) ENVIRON's turning basin study in the USR. While this subsection describes findings related to the physical characteristics of sediment in the Saginaw River, findings related to contamination are described in Section 4.3.

In August of 1999, the ACOE collected surface sediment from 32 locations from the LSR-SC to SB. Eight samples were collected from the LSR-SC, 18 from the LSR-BC, and six from SB near the mouth of the Saginaw River. All surface sediment samples were analyzed for grain size based on the percent of sample comprised of sediment in eight size classes ranging from silt to cobbles. Sediment samples from the LSR-SC were, on average, made up of almost equal parts fine sand (40%) and silt (32%). There were no sediments greater in particle size than fine gravel. The sediment grain fractions from the LSR-BC surface sediments were similar to the samples from the LSR-SC with higher fractions of silt and clay than in the upstream reach. Silt and fine sand were the dominant sediment fractions making up, on average, 47% and 40% of the LSR-BC sediment samples. Finally, the sediment samples from SB were finer grained than the samples from both of the river reaches. On average, the largest components of surface sediments from SB were silt (63%) and fine sand (24%).

The surface sediment samples collected by ACOE were also analyzed for total organic carbon (TOC). The ACOE samples show that the average TOC in surface sediment from the Saginaw River was lowest in the upstream reach and increased moving downstream and into Saginaw Bay. Average TOC content was 1.3%, 2.1%, and 2.9% in the LSR-SC, LSR-BC, and SB, respectively. In the LSR-SC, TOC ranged from 0.6% to 2.6%. In the LSR-BC, TOC ranged from 0.2% to 3.5%. In the SB, TOC ranged from 2% to 3.3%.

In December 2004, CH2MHill (2005) conducted a probing study to measure the approximate thickness of soft/unconsolidated sediment in the USR. Sediment was manually probed along 19 transects located at 0.25 mile intervals along the 5-mile reach. Probing was conducted at 5 to 12 locations along each transect, depending upon the river width, variability in water depth and variability in sediment thickness along adjacent transects. A total of 139 locations were probed for depth. Sediment and water depths were recorded at each location. The probe was constructed of 5/8 in diameter steel with graduated length markings, made up of 4 ft long section. It was capable of recording the thickness of unconsolidated materials up to approximately 28 ft below the water surface.

CH2MHill (2005) reported that the thickness of unconsolidated deposits generally ranged from 5 ft to 8 ft, with an average of 6.8 ft. Water depths at the probing locations averaged 11.3 ft, with a maximum of 22 ft at one location. Refusal was encountered at all but 5% of the probing points (i.e., seven locations). In these cases, the depth and flow rate of the water caused the steel rod to bow. Probing results are summarized in Table 2-2.

CH2MHill (2005) observed clay or silt on the end of the probe at approximately 33% of the monitoring points, indicating that the underlying glacial till was encountered and the unconsolidated deposit had been completely penetrated. A general trend of increasing thickness was observed from the southern/eastern river bank toward the mid-river and the northern/western river bank.

Sediment core samples collected during CH2MHill's sediment study were analyzed for grain size. A total of 31 grain size samples were collected at 15 locations. Samples were collected near the river-sediment interface and, where sediment core length permitted, at least one other interval from 2 ft to 6 ft below the river surface. The Unified Soil Classification System (American Society for Testing and Materials [ASTM] D2588-00) was used to classify the lithology of the sediment samples. The majority of samples were either sand (61%) or silty sand/sand with silt (10%). The remaining sediment samples were fine-grained sandy silts (26%) or clays (3%). More than 80% of the locations had sand at the sediment-river interface. Approximately 50% of the locations had sand or sand and gravel throughout the entire vertical interval, while the others were somewhat more fine (silty sand) or fine (silt or clay) at depth. Grain size results are summarized in Table 2-3.

CH2MHill's (2005) sediment samples were also analyzed for TOC. TOC in USR sediment was found to be relatively low, and was only detected in 14 out of 31 samples (detection limit was 100 milligrams per kilogram [mg/kg]). TOC concentrations ranged from 1,051 mg/kg (0.1%) to 22,975 mg/kg (2.2%) and averaging 4,514 mg/kg (0.5%) (one half of detection limit was used for non-detect results to calculate average concentrations). The average TOC of sediments from the USR is lower than the average TOC of any of the downstream reaches sampled in 1999 by ACOE (discussed above). Therefore, these results are consistent with the trend of steadily increasing sediment TOC moving from the head of the Saginaw River downstream and out into Saginaw Bay.

In 1990, Arthur et al. (1996) characterized seven stations on the Saginaw River and described the degree of embeddedness (or fines) as greater than or equal to 50%. The seven stations were evenly distributed along the river, with Station 1 located at the mouth of the river and Station 7 located at the confluence with the Tittabawassee River. Dominant substrate types were: Station 1 (sand, mud); Station 2 (sand, clay, mud); Station 3 (sand, clay, silt, mud); Station 4 (sand, clay, mud); Station 5 (mud, sludge, oil); Station 6 (sand, clay, mud, silt); and Station 7 (clay, sand, gravel). Cardenas et al. (1995) report that, "from field observations, it is known that the sizes of sediment particles in the Saginaw vary from less than 1micrometer (µm) to more than 1 millimeter (mm) but are predominantly in the silt and sand size range (10 µm to 1000 µm)."

In 2006, ENVIRON initiated a study on sediment characteristics within the turning basins; that work is ongoing. Eight deep sediment cores (to a maximum of 19 ft bgs) collected from the Ojibway Turning Basin in the USR were analyzed for grain size, bulk density, and TOC.

Percentages of each grain size fraction listed below are average values. Sediment was predominantly composed of sand (57%), as well as silt (31%) and clay (13%). Bulk density ranged from about 400 kilograms per cubic meter (kg/m^3) to 1,484 kg/m^3, and averaged 880 kg/m^3. TOC ranged from 0.1% to 3.5%, and averaged 1.5%. Dry weather conditions were sampled during three events in November and December 2006 at the Sixth Street Turning Basin in LSR-SC. Suspended solids were predominantly silt (64%), with lower fractions of very fine sand (27%) and medium sand (5%). The concentration of total suspended solids (TSS) in the water column ranged from 16 milligrams per liter (mg/L) to 156 mg/L, and averaged 49 mg/L. Fifteen sediment traps were deployed at three locations along each of five cross-river transects in the vicinity of the Sixth Street Turning Basin. Six bedload samplers were also deployed. Collections were dominated by silt (41%), as well as medium sand (21%), fine sand (11%), very fine sand (9%), and clay sand (5%).

2.8 Climate and Meteorology

The study area is characterized by a continental climate regime, with winter temperatures cold enough to sustain stable snow cover and relatively warm summer temperatures. The following climatological data reflects the period between 1971 and 2000 for the Saginaw MBS Airport AP weather station.[6] The mean temperature for the MBS Airport AP weather station is 47 degrees Fahrenheit (°F). While the minimum monthly mean temperature is 21.4°F (January), and the maximum average temperature is 71.2°F (July). The mean annual precipitation is 31.61 in, while mean monthly precipitation ranges from 1.57 in (February) to 3.95 in (September). The mean annual snow fall is 42.9 in. Wind in the region is predominantly from the west-southwest (averaged over the year), but is primarily from the west in the winter, the west-southwest in the spring, and the southwest in the summer and fall. The growing season averages 150 days and 115 days in the east and west portions of the Saginaw Bay watershed, respectively (Arthur et al. 1996).

2.9 Land Development

Prior to European settlement of the region in the early 1800s, central Michigan was home to members the Ojibwa or Chippewa nation. With the Saginaw Treaty of 1820, the Chippewa ceded a large area of land, including most of the Saginaw Bay watershed, to the United States.[7] Fur trappers settled in the area and, by 1830, about 30 people lived in Saginaw City. When the trappers moved on a few decades later, lumber moved in. By 1854, 29 mills were operating in the region. During the late 1800s, a commercial fishery developed in Saginaw Bay, while a

[6] http://cdo.ncdc.noaa.gov/climatenormals/clim20/mi/207227.pdf. .
[7] http://clarke.cmich.edu/nativeamericans/treatyrights/saginaw1820.htm

variety of industries developed alongside the river, including sawmills, foundries, barrel making, commercial fishing, machine shops, blacksmiths, grist mills, shipyards, salt mining, coal mining, and sugar manufacturing. By the 1900s, cleared forest had been converted to agricultural land. The early 20th century also saw further industrialization of the area, including oil drilling and manufacturing of motors, boats, ships, trucks, bicycles, and automobiles.

Today, land use is diverse, ranging from undisturbed natural settings to heavily industrialized urban areas, reflecting a regional economy that is centered on agriculture, industry, recreation, and forestry. Current land use in the watershed consists of: agriculture (46%), forest (29%), open lands (11%), urban (8%), wetlands (4%), and water (2%) (Arthur et al. 1996, PSC 2002). Figures 2-9a, 2-9b, and 2-9c illustrate the geographic distribution of different land use categories in the USR, LSR-SC, and LSR-BC areas, based on 2001 data from the USGS National Land Cover Data Set. This series of figures illustrates the dense residential, commercial, industrial, and transportation development of the vicinity of the USR (City of Saginaw) and the LSR-BC (City of Bay City). In contrast to that dense development surrounding Saginaw and Bay City, however, LSR-SC area and land immediately surrounding the cities is largely agricultural. The agricultural community produces sugar beets, corn, dry beans, barley, wheat, and potatoes. Livestock production consists of hogs, poultry, and beef and dairy cattle (PSC 2002, MDNR 1988). As further detailed in Section 2.12, there is limited and patchy distribution of forests and wetlands, primarily near Saginaw Bay, LSR-SC, and at the confluence of the Tittabawassee and Shiawassee Rivers. The total acreage and proportion of land in each land use type within the FEMA 100-year floodplain is summarized in Table 2-4. Property parcels are illustrated in Figures 2-10a, 2-10b, and 2-10c, for the USR, LSR-SC, and LSR-BC floodplains.

2.10 Water Body Use

The Saginaw River and Bay are used for navigation, water supply, wastewater discharge, commercial and recreational fishing, swimming, and hunting. The importance of the river, bay, and the watershed as wildlife habitat is discussed in Section 2.12; this discussion focuses on human use of the system.

The Saginaw River is used for navigational purposes – shipping cargo – between Saginaw Bay and the Sixth Street Turning Basin. Although the Saginaw River is not controlled by dams and locks, a channel is dredged through the river to allow freighter traffic, as further discussed in Section 3.1. In 2003 (the most recent year for which data were available), approximately 5.5 million tons of commodities were shipped (inbound) through the Saginaw River port, making it the second largest (inbound) port of Michigan’s 40 shipping ports, after Detroit (MDOT 2006).

Numerous large gravel piles along the banks of the Saginaw River stockpile construction materials following off-loading from cargo ships. In addition to conveying bulk commodities related to construction and agriculture, chemicals are shipped on the Saginaw River (MDOT 2006). To support such uses of the Saginaw River, shipping channels and navigational turning basins are maintained, as discussed in Section 3.1. In 2006, low water levels and limited navigational dredging activities hampered commercial navigation of the Saginaw River, forcing decreased loading ("light loading") of most cargoes and some carriers to decline service within the Saginaw River (Lake Carriers Association 2006). Indeed, two ships ran aground in the Saginaw River in 2006. The ACOE performed emergency dredging within the turning basin to keep the waterway open (Lake Carriers Association 2006).

Saginaw Bay serves as a drinking water source for the City of Bay City Municipal Water Treatment Plant, which draws its water supply from the bay via a 4-mi long, 4-ft diameter intake pipe.[8] The City of Bay City Municipal Water Treatment Plant provides water to several townships, Bay City, and Essexville. The Saginaw-Midland Municipal Water Supply Corporation draws water from Saginaw Bay and provides drinking water to a number of townships, as well as Saginaw, Midland, and Zilwaukee.[9]

As further detailed in Sections 3.2, 3.3, and 3.9, the Saginaw River serves as a receiving water for various municipal and industrial wastewater discharges. Dischargers include the cities of Saginaw, Bay City, and Essexville and numerous non-municipal dischargers with National Pollution Discharge Elimination System (NPDES) permits (Section 3.9). Past industrial inputs include wastes from chemical, plastics, can manufacturing, and photographic industries (Rossman et al 1983).

The Saginaw River and Bay's fishery has been important to Native Americans since before European settlement of the area occurred in the mid-1800s. Commercial fisheries were first established in the Saginaw Bay area in the 1830s (Lanman 1839 as cited by Keller et al. 1987). As discussed by PSC (2000) and Hendrix and Yocum (1984), commercial fishing became a major industry in many ports along Saginaw Bay peaking just after the turn of the century when a record 14.2 million pounds of fish were harvested. The town of Bay Port was once known as the world's largest freshwater fishing port (Lynn 1979 as cited by Hendrix and Yocum 1984).

Since the turn of the century, fish production gradually declined to a low of 1.4 million pounds (i.e., 10% of the peak production 70 years earlier) in 1974 (Keller et al. 1987). Lake

[8] http://www.baycitymi.org/2002design/PDF%20Files/06report.pdf
[9] http://www.midland-mi.org/government/departments/utilities/whitestone.htm#Saginaw-Midland

sturgeon had essentially disappeared from Saginaw Bay by 1940. The composition of the catch has also changed over time. For example, in 1954, lake herring comprised 23% of the catch, but after 1962 virtually no herring were harvested from the bay. Yellow perch comprised 48% of the catch in 1966, but were only 8% in 1983. Reasons for the collapse of the commercial fishery in Saginaw Bay are attributed to:

- Predation of lake trout, whitefish, and walleye by introduced sea lampreys (Hile and Buettner 1959 as cited by Hendrix and Yocum 1984);
- Competition with the introduced species, such as carp, alewife, and rainbow smelt (Beeton 1969 as cited by Hendrix and Yocum 1984);
- Overfishing (Beeton 1969 as cited by Hendrix and Yocum 1984):
- Toxic pollution increasing mortality or reducing reproduction (Beeton 1969 as cited by Hendrix and Yocum 1984);
- Adverse effects on recruitment of some species from sedimentation on spawning beds and smothering of the eggs (Schneider 1977 as cited by Hendrix and Yocum 1984);
- Destruction of wetlands critical to spawning of some species (Hendrix and Yocum 1984); and
- Construction of dams, which blocked spawning tributaries in the Saginaw River (PSC 2000).

In the 1970s, commercial fishing and sportfishing competition for declining populations of perch and walleye in Saginaw Bay prompted the state to impose severe restrictions on commercial fishing for perch and eventually a complete ban on commercial walleye fishing (PSC 2000). Commercial fishery harvests in Saginaw Bay for the period 1980 through 1993 are illustrated in Figure 2-11. There are currently 26 commercial fishing licenses for operating trap nets targeting yellow perch and white fish in Saginaw Bay, although not all licenses are fished (J. Baker, MDNR, personal communication 8/31/2007).

More recently, natural recruitment of walleye and perch in Saginaw Bay has greatly increased. The unprecedented increase in reproductive success in Saginaw Bay from 2003-2005 was largely attributed to a sharp decline in adult alewife abundance, a known predator on walleye fry (Fielder et al. 2007).

Saginaw Bay is also used intensively for recreation, particularly fishing and hunting. Sportfishing activity from 1940 through the 1970s focused on yellow perch, walleye, northern pike, smallmouth and largemouth bass, crappie, and blue gill in the relatively shallow inner bay areas (PSC 2000). During that period and into the 1990s, there was little recreational fishing within the Saginaw River (PSC 2000). Beginning in the late 1970s, Michigan Department of Natural Resources (MDNR) cooperated with local sportfishing organizations to begin a stocking program in Saginaw Bay to reestablish walleye as the predominant predator in the bay (PSC 2000). While Saginaw Bay NWI (1994) describes the bay as a world-class walleye sport fishery, Fielder and Baker (2004) indicate that further and complete recovery of the fishery will not occur without additional management intervention. Indeed, the current abundance of walleye in the bay is estimated to be less than one-third of that which existed in the bay prior to the population collapse that occurred in the 1940s. Sportfishing in the outer bay has become increasingly important, as the control of sea lamprey in Lake Huron has allowed stocked lake trout, brown trout, steelhead, and Chinook salmon to survive (PSC 2000).

Recreational fishing in the river is guided by a fish consumption advisory issued by the Michigan Department of Community Health (MDCH) as updated (MDCH 2007). As detailed in Table 2-5, a fish consumption advisory remains in effect for the Saginaw Bay and River Watershed area. A survey conducted as part of the University of Michigan dioxin exposure study[10] found that residents of Tittabawassee and Saginaw River and Bay region have consumed fish from the Tittabawassee River, Saginaw River, or Saginaw Bay within the last five years.

Some areas around Saginaw Bay are also used for hunting. Mikula (1987) reported that the Michigan Department of Conservation (which was subsequently renamed MDNR) adopted long-range management and acquisition goals to establish wildlife management and public use areas around Saginaw Bay in the early 1940s. As a result, six areas were purchased around Saginaw Bay, totaling 8,362 acres. These game management areas are also used for bird watching and nature study (Mikula 1987).

2.11 Demographics

U.S. Census Bureau[11] data on the population and demographics of the cities of Saginaw and Bay City in 2000 are detailed in Table 2-6. As illustrated in Table 2-6, the population of Saginaw is about twice that of Bay City (61,799 and 36,817 residents, respectively). Residents of Saginaw are also somewhat younger than those of Bay City (median ages of 30.7 and 35.2, respectively). The population of Bay City is predominantly Caucasian, while the majority of the population of Saginaw is African American (43.3%) or Hispanic or Latino (11.7%). The median

[10] www.sph.umich.edu/dioxin/
[11] http://quickfacts.census.gov/qfd/states/26/26017.html

household income of Bay City ($30,425) is greater than that of Saginaw ($26,485). Conversely, the percent of the population living below the poverty line is greater in Saginaw (28.5%) than in Bay City (14.6%). Over the last four decades, the population of Bay County has been relatively stable, ranging from 107,042 in 1960 to 119,881 in 1980 and declining since then (2006 estimate is 108,390). The population of Saginaw County ranged from 190,752 in 1960 to 228,059 in 1980 and has also declined since then (2006 estimate is 206,300).

2.12 Ecology

This section describes the general ecological characteristics of the USR, LSR, and SB. Habitat types are first described based on the Michigan Natural Features Inventory (MNFI 2007). Second, this section describes federally-listed and state-listed threatened, endangered, candidate, and species of special concern known to occur within the identified natural communities, followed by a general summary of common species expected to be present within the natural communities. This section closes with a discussion of exotic and invasive species.

2.12.1 Habitat Types and Distribution

The MNFI issued a draft list and descriptions of Michigan's natural communities in April 2006 (MNFI 2006). According to the general distribution maps provided by MNFI, the USR, LSR, and SB may include nine natural community types:

- Dry-mesic northern forest (pine-hardwood forest);
- Great Lakes marsh;
- Lakeplain oak openings;
- Lakeplain wet prairie;
- Lakeplain wet-mesic prairie;
- Mesic northern forest (northern hardwood forest; hemlock-hardwood forest);
- Mesic southern forest (southern hardwood forest);
- Poor conifer swamp; and
- Southern swamp.

Descriptions of these natural communities are excerpted from MNFI[12] and are tabulated in Table 2-7. Of these natural communities, Great Lakes marsh, lakeplain oak openings, lakeplain wet prairie, and lakeplain wet-mesic prairie are listed by MNFI as critically imperiled (S1) or imperiled (S2) or rare (S3). Of these rare communities, Great Lakes

[12] http://web4.msue.msu.edu/mnfi/pub/abstracts.cfm

marsh and the lakeplain oak and prairie communities may be found within the LSR and SB. Other communities are more common and broadly distributed throughout the study area, particularly the mesic and swamp forested communities.

Wetlands within the study area are also classified by the National Wetland Inventory (NWI), based on Cowardin et al. (1979). Figures 2-12a through 2-12c illustrate the distribution of NWI-mapped wetlands within the USR, LSR, and SB floodplains, respectively. Because the NWI classification system differs from that of MNFI, the NWI maps do not show the extent and location of Great Lakes Marsh, lakeplain wet prairie, and lakeplain wet-mesic prairie.

2.12.2 Threatened and Endangered Species

Federal-listed and state-listed threatened, endangered, and other rare species of plants and animals were compiled from the MNFI. A database search was conducted of the county element data (for Bay, Midland, and Saginaw Counties) and rare species explorer (by natural community). A total of 6 reptile, 4 fish, 17 bird, 3 insect, 5 mussel, and 26 plant species are associated with those natural communities located within these counties for which there are detailed abstracts. Reported habitat associations and county occurrence data for these species are summarized in Table 2-8.

Of the rare species identified Table 2-8, two birds and one plant are federally-listed threatened species. One reptile species is a candidate for listing under the federal Endangered Species Act. According to the MNFI, the bald eagle is a federally threatened species that might inhabit areas of both Saginaw and Bay Counties. The United States Fish and Wildlife Service (USFWS) announced its decision to de-list the bald eagle within the coterminous U.S. on June 28, 2007.[13] The prairie fringed orchid is a federally threatened plant species that is known to occur in bogs and wet prairies in Saginaw County. The Eastern Mississauga rattlesnake is federally listed as a candidate species. It can be found in bogs, wet meadows, and floodplain forests in Bay and Saginaw Counties (MNFI 2007) and may be found in the remaining wetlands and wetter habitat types in the study area.

2.12.3 Wildlife

The wildlife present within the Saginaw River floodplain is typical of that supported by the remnant natural forest and wetland communities. Despite the highly fragmented nature

[13] www.fws.gov/easternwashington/documents/Final%2oeagle%20delist%20NR%206-28-2007.pdf

of existing habitat along the river, several mammal species likely inhabit the area. Wildlife surveys have not been conducted throughout the floodplain and the status of local populations has not been determined. However, resident game species are expected to include white-tail deer (*Odocoileus virginianus*), ring-necked pheasant (*Phasianus colchicus*), and wild turkey (*Meleagris gallopavo*). Smaller mammals known to use wetland, aquatic, and terrestrial habitats in the floodplain include beaver (*Castor canadensis*), muskrat (*Ondatra zibethica*), mink (*Mustela vison*), ground hog (*Marmota monax),* and raccoon (*Procyon lotor*).

The status of local bird populations has not been determined but a variety of resident and migratory birds use the remaining habitats in the vicinity of USR, LSR, and SB. The Saginaw River and associated wetlands support many migratory and resident species of waterfowl, such as blue-winged teal (*Anas discors*), green-winged teal (*Anas crecca*), Northern shoveler (*Anas clypeata),* common goldeneye (*Bucephala clangula*), and mallard (*Anas platyrhynchos*). Piscivorous birds common in the Saginaw River, Bay, and associated wetland habitats include the belted king fisher (*Ceryle alcyon*), great blue heron (*Ardea herodias*), common merganser (*Mergus merganser*), red-breasted merganser (*Mergus serrato*r), and common loon (*Gavia immer*). Some of the many migratory songbirds likely to inhabit the area include olive-sided flycatcher (*Contopus cooperi*), Eastern kingbird (*Tyrannus tyrannus*), golden-crowned kinglet (*Regulus setrapa*), Northern oriole (*Icterus galbula*), and Eastern bluebird (*Sialia sialis*). Among the raptors reportedly present in the study area (Peters 2001) are great horned owl (*Bubo virginianus*), red-tailed hawk (*Buteo jamaicensis),* turkey vulture (*Cathartes aura*), Eastern screech owl (*Megascops asio*).

2.12.4 Fish

The relatively shallow waters of Saginaw Bay provide habitat for a wide variety of fish and other aquatic species and are among the most productive fish habitats in the Great Lakes. Average fish densities in Saginaw Bay are about ten times those found in Lake Huron (Saginaw Bay NWI 1994). The Saginaw River has been developed largely into a controlled transportation corridor with limited stream habitat diversity, although recent work by MDNR suggests the river may function as an important nursery area for walleye fry from the Tittabawassee River (J. Baker, MDNR, personal communication, 8/31/2007).

Popular game species targeted by sportfishing anglers include: channel catfish, (*Ictalurus punctatus*), lake sturgeon (*Acipenser fulvescens*), largemouth bass (*Micropterus* *salmoides*), Northern pike (*Esox lucius*), smallmouth bass (*Micropterus dolomiteu*), steelhead (*Oncorhynchus mykiss*), walleye (*Sander vitreus*), white bass, (*Morone chrysops*), and white sucker (*Catostomus commersoni*) (PSC 2005). Walleye is the most popular recreational fish in Saginaw Bay with channel catfish and smallmouth bass also supporting popular fisheries. Yellow perch and channel catfish are commercially harvested in Saginaw Bay (Fielder and Thomas 2006).

In general, slow or backwater marshy areas along rivers tend to have high species diversity and abundance of fish. There is no documentation of where these habitat types occur on the Saginaw River, but they are known to occur in the Shiawassee National Wildlife Refuge, which is located at the confluence of the Tittabawassee and Shiawassee Rivers. Large numbers of shiners, crappie, sunfish, and largemouth bass were found in the refuge, along with bowfin, rock bass, yellow perch, and northern pike (Zollweg and Hill 2002).

Although no recent fish sampling reports or fish population studies have been identified for any reach of the Saginaw River, but MDNR conducts annual surveys of walleye, yellow perch, and alewife populations in Saginaw Bay using trawls and gillnets (Fielder et al. 2000, Fielder and Thomas 2006). In addition to the Saginaw Bay sampling program, MDNR tags walleyes spawning in the Tittabawassee River every spring (Fielder et al. 2000, Fielder and Thomas 2006) and monitors stocked and naturally produced walleye populations in the watershed (Fielder and Thomas 2006). Finally, since 1995, USFWS-Alpena Fishery Resource Office has monitored lake sturgeon caught incidentally in the commercial fishery in Lake Huron, including Saginaw Bay, since 1995.[14]

The fish community in Saginaw Bay has undergone considerable changes during the past decade. Since 2003, alewives have declined in Lake Huron and have not been using Saginaw Bay for spawning (MDNR 2006, 2007). Concurrent with the decline in adult alewives, walleye and yellow perch production has increased substantially in 2003 and 2004 (Fielder and Thomas 2006). Alewife predation is believed to have been the primary factor limiting walleye production with spawning habitat quality and availability a secondary factor (Fielder and Thomas 2006, Fielder et al. 2007). Sport fishing is not currently considered a limiting factor on the Saginaw Bay walleye population (Fielder and Thomas 2006).

Larval survival studies conducted in 1987 and 1988 found large numbers of walleye

[14] http://www.fws.gov/midwest/alpena/lakesturgeon.htm#lakehuron

larvae moving into the Saginaw River from the Tittabawassee River, but relatively few were observed moving from the Saginaw River to Saginaw Bay, the assumed nursery area (Jude 1992). Therefore, larval mortality in the Saginaw River was believed to be high. However, in light of recent increases in walleye recruitment, MDNR fish biologists now suspect that many walleye larvae rear in the Saginaw River, rather than the bay (J. Baker, MDNR, personal communication, 8/31/2007). No studies have been conducted, however, documenting the rearing areas for walleye larvae from the Tittabawassee River.

Saginaw Bay also supports a diverse assortment of native and exotic fish species that serve as potential prey for fish and avian predators. Although alewives have declined, native benthic species, such as spottail shiners, trout-perch, gizzard shad, and emerald shiners, make up a significant prey base (Fielder and Thomas 2006). The invasive round goby (*Neogobius melanostomus*) has not been sampled in the Saginaw River but it is present throughout Saginaw Bay (Fielder and Thomas 2006). The impact of round goby colonization is unclear. They are known to displace native fish and eat smaller native fish and their eggs (J. Baker, MDNR, personal communication, 8/31/2007). However, they also feed on invasive zebra mussels (*Dreissenia polymorpha*) and may ultimately mitigate some of the effects zebra mussels have had on the food web in the bay (Jude 1996). Walleye, freshwater drum, channel catfish, and yellow perch have all incorporated round gobies into their diets (Fielder and Thomas 2006).

2.12.5 Amphibians and Reptiles

Although the status of populations of amphibians and reptiles within the Saginaw River floodplain has not been determined, a number of amphibians, snakes, and turtles are found in the vicinity of USR, LSR, and SB, some of which are rare species associated with declining or imperiled natural plant communities (Table 2-8). Common amphibian and reptile species expected to inhabit the USR, LSR, and SB include those associated with wetlands and adjacent forested uplands, such as the western chorus frog (*Pseudacris triseriata triseriata*), wood frog (*Rana sylvatica*), eastern tiger salamander (*Ambystoma tigrinum tigrinum)*, common garter snake (*Thamnophis sirtalis*), and painted turtle (*Chrysemys picta*).

2.12.6 Exotics and Invasive Species

There are 146 exotic or invasive species inhabiting the Great Lakes region (PSC 2000). Many such species were introduced unintentionally, such as the sea lamprey (*Petromyzon* *marinus*) and alewife (*Alosa pseudoharengus*), which arrived in the Great Lakes as a result of the building of the Welland Canal. The canal provided species capable of living in both freshwater and saltwater relatively easy access to the lakes. Other fishes introduced unintentionally that have had adverse ecological impacts include gobies (*Neogobius spp*.) and spiny water flea (*Bythotrephes cederstroem*i) (Albert 2001).

Other aquatic species [including zebra mussel, round goby, and ruffe (*Gymnocephalus cernuus)*] were accidentally introduced to the Great Lakes in ballast water discharged from ocean-going vessels. A variety of studies examined the effects of zebra mussel colonization on Saginaw Bay. The documented effects included decreases in water column chlorophyll concentrations and increases in water clarity (Fahnenstiel et al. 1995a,b); significant changes in water column nutrient concentrations (Johengen et al. 1995); shifts in the distribution of primary production in Saginaw Bay from phytoplankton to benthic algae and macrophytes (Fahnenstiel et al. 1995a,b); shifts in the benthic algal and macroinvertebrate communities including a decline in the native shrimp species (*Diporeia* spp.; Lowe and Pillsbury 1995, Nalepa et al. 2003). In addition to the broad ecological impaces, zebra mussels have adversely affected water supply intakes and distribution lines.

In contrast with these accidental introductions, the Chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) were intentionally introduced into the Great Lakes in response to declining populations of native species that had been over-fished and/or adversely affected by the early exotic invaders and to help control introduced alewife populations. In addition, rainbow trout (*O. mykiss*) was likely introduced in Michigan in the 1870s to augment the local fisheries. Common carp (*Cyprinus carpio*) and rainbow smelt (*Osmerus mordax*) were also intentionally introduced in the 1800s to provide fisheries for recent immigrants unfamiliar with local species.

A number of exotic invasive plants have altered the structure and composition of wetland and upland communities. Because they lack natural biological control agents (e.g., invertebrates that co-evolved with them), invasive plants often out-compete native species. In wetlands, examples of such invasive plant species include purple loosestrife (*Lythrum salicaria*), reed canarygrass (*Phalaris arundinacea*), giant reed (*Phragmites australis*), Eurasian milfoil (*Myriophyllum spicatum*), and curly-leaf pondweed (*Potamogeton crispus*).[15]

[15] http://web4.msue.msu.edu/mnfi/education/factsheets.cfm

3. SCALE AND EFFECTS OF ANTHROPOGENIC ACTIVITIES

Numerous activities have influenced conditions in the Saginaw River and Bay, including discharges from industries and municipalities, urban stormwater discharges, agricultural runoff, releases from hazardous waste sites, and physical alterations of the river and floodplain. Such anthropogenic activities have likely contributed to degraded water quality conditions and impairment to designated water uses. As a result of that impairment, the International Joint Commission (IJC) listed the Saginaw Bay Basin as a Great Lakes AOC. Of the 14 potential beneficial use impairments listed in the Great Lakes Water Quality Agreement (GLWQA), 12 were considered to be impaired in the Saginaw River and/or Saginaw Bay in 1994 (Saginaw Bay NWI 1994). Nutrient enrichment contributed to the greatest number of use impairments (eight), followed by sedimentation (four). Toxic contaminants were attributed to three use impairments. This section describes the nature, timing, location/spatial extent, effects and related data (where available) for 13 types of anthropogenic activity that historically and/or currently influence conditions on the river and the bay.

Much of the information presented below was derived from Environmental Data Resources, Inc. (EDR), which was contracted to conduct a search of federal and state environmental databases for all sites within the floodplain of the Saginaw River. Because chemicals associated with sites immediately adjacent to but not within the floodplain may have migration pathways into the floodplain (e.g., stormwater system discharge, surface runoff, atmospheric deposition, or groundwater flow), the EDR search area included a quarter mile buffer around the FEMA 100-year floodplain of the Saginaw River. The EDR report consists of a list of all sites that have been included on databases such as the federal National Priorities List (NPL), Resource Conservation and Recovery Act (RCRA) hazardous waste generators and handlers, toxics release inventory (TRI), NPDES, the Michigan Department of Environmental Quality (MDEQ) contaminated sites list, and others. Sites for which sufficient location information was available were mapped and summarized. Sites with poor or inadequate location information (orphan sites) were listed in the EDR report, but were not mapped and therefore, were not included in this analysis. The sites included in the EDR report for the floodplains of the USR, LSR-SC, and LSR-BC are mapped in Figures 3-1a through 3-1c. In addition, the broader scientific literature was reviewed for more general information on subjects such as physical alterations, municipal WWTPs, CSOs, eutrophication, and soil erosion and sedimentation.

3.1 Physical Alterations

Physical alterations to the Saginaw River channel, banks, and floodplains began with the development of the first sawmills in 1835. Since then, the Saginaw River floodplain has been almost completely converted to agricultural and urban land uses, while the channel has been developed into an important transportation corridor, which has been maintained by extensive navigational dredging. Such anthropogenic alterations can affect erosional patterns and sediment transport processes in the river, which in turn can adversely affect vegetation and riverine habitats. Typically, the end result is a loss of wetlands and side channel habitats.

In the urbanized areas of Bay City and Saginaw, extensive river bank development includes bulkheads and dock facilities along most of the channel banks. In less urbanized areas, roads and/or railroads run along both sides of the river. The banks are maintained through fill and dikes to contain high flows and prevent erosion. As noted in Section 2.4, only LSR-SC displays some characteristics of a meandering fluvial system. The extensive modifications that have been made to much of the river have limited and/or simplified those nearshore fish and wildlife habitats that occur at the river and floodplain interface.

Over 76% of the Saginaw River floodplain has been modified through urban and industrial development or agricultural development[16]. Within the USR floodplain, land use is classified as 61% developed and 13% cultivated crops and pasture lands. Within the LSR-SC floodplain, land use is classified as 23% developed and 58% as cultivated crops and pasture lands. Within the LSR-BC floodplain, land use is classified as 24% developed and 48% cultivated crops and pasture lands. Section 2.12 of this CCR identifies a number of wetland and forest habitats that have been totally eliminated or reduced to very small areas by agricultural and urban developments.

Alterations to the river channel have also been extensive. The Saginaw River channel is a federally authorized commercial navigation project. From north to south, the entire channel extends from deep water, 14 miles into Saginaw Bay through the mouth of Saginaw River and 22 miles upstream to the city of Saginaw (ACOE 2004). The spatial extent and timing of such dredging activities are illustrated in Figures 3-2 a through 3-2d. ACOE navigational dredging volumes and placements are summarized in Table 3-1. Remediation dredging conducted in 2000 and 2001 removed approximately 345,000 cubic yards of polychlorinated biphenyls (PCB)-contaminated sediments (USFWS 1999, PSC 2000).

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16 Land use data is from the USGS 2001 National Landcover Data Set available at: http://www.mrlc.gov/zones/show_data.asp?szone=8

The ACOE maintains channel depths at 27 ft in the entrance channel to the mouth of the river, 26 ft through the mouth, 25 ft to the Grand Trunk Western Railroad bridge at Bay City, thence 27 ft to the CSX railroad bridge in Saginaw, and 16.5 ft to the Holland Avenue bridge in Saginaw. Above the Holland Avenue bridge in Saginaw depths in the river vary from 7 ft to 15 ft for about 2.8 miles to Green Point (NOAA 2007). Maintained turning basins in the river (and their respective depths) include: 1) Essexville (25 ft); 2) Airport (22 ft); 3) Carrollton (20 ft); 4) Sixth Street (20 ft); 5) Grand Trunk Western Railroad bridge (15 ft), and 6) Holland Avenue bridge (15 ft) (NOAA 2007).

Currently, dredged material from Saginaw Bay and the lower 4.7 miles of the Saginaw River is placed in the Saginaw Bay Confined Disposal Facility (CDF), which is located in Saginaw Bay approximately 1.9 miles from the mouth of the Saginaw River and directly adjacent to the Saginaw Bay channel. The Saginaw Bay CDF contains sediment dredged both for navigation and remediation purposes. The dredged material from the Upper Saginaw River was historically placed in the Middle Ground Island CDF, which was filled in 1983. In 2004 and 2005, the ACOE examined alternatives for future dredged material disposal and completed the National Environmental Policy Act process. The ACOE concluded that the preferred alternative was to develop an upland dredged material disposal facility in Zilwaukee Township on a large parcel west of the Saginaw River approximately 11 miles upstream of the mouth of Saginaw River (ACOE 2004). A Finding of No Significant Impact was issued in March of 2005.

During dredging, environmental effects may arise due to the excavation of sediments at the bed, loss of material during transport to the surface, overflow from the dredger while loading, and loss of material from the dredger during transport. Dredging also removes organisms in the dredged area and changes the contour of the river or lake bottom. In the Saginaw River and Bay, environmental effects of dredging are generally expected to be related to short term increases in turbidity and disturbance of the benthos. Aside from the navigation benefits derived from dredging, the process, if properly conducted, contaminated sediments may be removed from the system by dredging.

Because the Saginaw Bay CDF covers lake-bottom habitat, it has altered the substrate upon which the benthic community lives (Miller 2003). To test the potential for release of contaminants from the CDF, a pilot field study was conducted at the Saginaw Bay CDF, using caged fish, clams, and plants deployed inside and outside of the CDF dikes; there was no evidence of significant contaminant transport during sediment disposal operations (USEPA

1994). Modeled simulations of contaminant release also concluded that any releases are not likely to be ecologically significant (Miller 2003).

The CDF dikes create reef-like habitat for fish, while the interior areas support dense vegetation and a temporary habitat for fish and wildlife (Miller 2003). The mounded dredged material within the CDF provides nesting habitat for migratory waterfowl (Miller 2003). Management of the dredged material is designed to minimize possible uptake of contaminants by wildlife from the CDF (Miller 2003). Miller (2003) concluded that the removal and confinement of sediments from the navigation channels and floodplains lowers exposure to biological communities.

3.2 Municipal Wastewater Treatment Plants

Four municipal WWTPs are located on the Saginaw River: the Saginaw WWTP, the Buena Vista Charter Township WWTP, the Bay City WWTP, and the Essexville WWTP (Figure 3-3). In addition, the West Bay County Regional WWTP is located within the floodplain of the LSR, and both the Saginaw Township WWTP and the Saginaw Township-Center Road WWTP landfill are located on the Tittabawassee River. WWTPs influence water quality through discharge of treated wastewater that contains residual TSS, nutrients (phosphorus and nitrogen), as well as some toxic chemicals. In addition, treated wastewater may be oxygen-depleted, relative to the unimpaired range of 8 mg/L to 10 mg/L dissolved oxygen. Contributions of TSS can adversely affect the turbidity of the receiving water body, while addition of nutrients can contribute to eutrophication (discussed further in Section 3.5). Low dissolved oxygen levels in the Saginaw River can pose an imminent hazard to aquatic life. The following information on each is drawn from the Fact Sheets for their NPDES permit applications as currently available from MDEQ.

The Saginaw WWTP[17] initially treats waste using screening (bar screens) and grit removal channels. Primary (i.e., physical) treatment continues at the facility's primary settling tanks. Secondary (i.e., biological) treatment is accomplished using activated sludge in aeration basins and final settling tanks. A chemical feed is directed to the waste stream prior to final settling in order to facilitate phosphorus removal. Disinfection at the facility is chlorine-based, while de-chlorination is accomplished via a sulfur dioxide chemical feed. Effluent data from January 1, 2005 to May 31, 2006 reported on the NPDES fact sheet reports maximum monthly loading of TSS and total phosphorus as high as 218 mg/L and 1.3 mg/L, respectively, depending on the monitoring location. At monitoring point 001A, detectable concentrations of mercury and PCBs

[17] http://www.deq.state.mi.us/documents/deq-water-npdes-publicnotice-MI0025577_FS.pdf

were reported (8.8 nanograms per liter [ng/L] and 0.2 micrograms per liter [µg/L], respectively). Although dissolved oxygen levels vary across monitoring points, a minimum daily concentration of 3.3 mg/L was reported at monitoring point 001A.

Limited information regarding the Buena Vista Charter Township WWTP was identified from public sources. In August 2006, MDEQ issued a major permit to this WWTP to discharge 2.2 million gallons daily (MGD) of treated municipal wastewater to the Saginaw River.[18] The NPDES permit number is MI0022497. That permit became effective January 1, 2007 and expires October 1, 2010. It is a publicly-owned WWTP for non-industrial waste.[19]

As detailed in the NPDES Fact Sheet,[20] the Bay City WWTP services Bay City, Bangor Township, Hampton Township, Monitor Township, and Portsmouth Township. Treatment includes grit removal, grinding, primary settling, secondary treatment with trickling filters, secondary clarification, and ultra-violet disinfection. As of August 1, 2006, the maximum monthly TSS and phosphorus concentrations were 15 mg/L and 0.8 mg/L, respectively. The minimum daily dissolved oxygen was 3.7 mg/L.

As detailed in the NPDES Fact Sheet,[21] the Essexville WWTP provides secondary treatment of municipal wastewater for the city of Essexville. The facility consists of a screen, mechanical grit removal, primary clarifiers, oxidation towers, final clarifiers, a chlorination contact chamber, and a de-chlorination chamber. As of April 11, 2005, the maximum monthly TSS and phosphorus concentrations were 10 mg/L and 0.3 mg/L, respectively. The minimum daily dissolved oxygen was 3.9 mg/L.

3.3 Combined Sewer Overflows

As detailed by MDEQ (2005b), many of the municipal sewer systems within the Saginaw River valley are old systems, which convey both sewage and stormwater (combined in the same pipe system) to WWTPs. Because such systems cannot handle the volume of water associated with some storm events and snowmelt, combined sewer systems are typically designed with overflow points in the sewer system and/or the WWTP. Overflow events triggered by some storms and storm melt water in combined sewer systems are referred to as CSOs. CSO events are pertinent to the overall conditions of the Saginaw River and Bay because the release of partially treated sewage during storm events contributes nutrients (e.g., phosphorus and

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[18] http://www.deq.state.mi.us/documents/deq-water-npdes-bulletins-September_06.pdf
[19] http://www.deq.state.mi.us/documents/deq-wb-npdes-prmtlist.xls
[20] http://www.deq.state.mi.us/documents/deq-wb-npdes-publicnotice-MI0022284-FS.pdf
[21] http://www.deq.state.mi.us/documents/deq-water-npdes-publicnotice-MI0022918_FS.pdf

nitrogen), solids, pathogens, and municipal and industrial chemical waste to the river and subsequently to the bay. Such releases likely exacerbate many of the secondary effects discussed in other subsections, such as eutrophication, suspended solids, and toxics loading.

As part of MDEQ's CSO corrective action programs, many combined sewer systems (including the system in Saginaw) have recently installed retention/treatment basins (RTBs), which are designed to capture the combined sewage and rain water (MDEQ 2005b). The RTBs hold the combined sewage long enough to provide partial treatment and disinfection before the discharge is released into waters of the state during periods of intense precipitation (MDEQ 2005b). The seven RTBs associated with the Saginaw WWTP treat stormwater via settling, skimming, and disinfection of all CSOs.[22] Based on data from 2000 through 2005, MDEQ (2005b) reports a statewide decreasing trend in the volume of CSO events. However, discharges to the Saginaw River more than doubled from 2005 to 2006, as detailed below.

MDEQ tracks CSO discharges by both the storm event and the WWTP that is associated with the outfall(s) where the release occurs.[23] A total of 26 outfalls release treated sewage water from the three WWTPs located on the Saginaw River. During CSO events, the WWTP outfalls release partially treated sewage to the Saginaw River. The majority of these outfalls (20) are associated with the Saginaw WWTP (003, 004, 004R, 005, 005R, 006, 006R, 007, 007R, 011R, 026, 027, 028, 030, 031, 032, 034, 035, 037R, 039, and 040). Five outfalls are associated with the Bay City WWTP (013, 014, 018, 040, and 048) and one (002) is associated with the Essexville WWTP.

In 2005, MDEQ (2005b) reported that 448 million gallons (MG) of partially treated sewage were released to the Saginaw River. This volume included four CSO events at the Bay City WWTP (189 MG), eight CSO events at the Essexville WWTP (9 MG), and six CSO events at the Saginaw WWTP (250 MG) (MDEQ 2005b). In 2006, CSO events released one billion gallons of partially treated sewage to the Saginaw River on 25 days. Of this total, 72% was associated with the Saginaw WWTP, 27% was associated with the Bay City WWTP, and 1% was associated with the Essexville WWTP.[24]

3.4 Eutrophication

At least since the 1960s, Saginaw Bay waters have been classified as eutrophic (PSC 2000). Eutrophic waters are high in nutrients (e.g., nitrogen and phosphorus), which promote biological

[22] http://www.deq.state.mi.us/documents/deq-water-npdes-publicnotice-MI0025577_FS.pdf
[23] http://www.deq.state.mi.us/csosso
[24] http://www.deq.state.mi.us/csosso

growth (particularly algae). The high biological oxygen demand of eutrophic waters reduces dissolved oxygen in the hypolimnion (i.e., the bottom and most dense layer in a thermally stratified lake). Under natural conditions, eutrophication occurs over thousands of years; however, human activities that introduce nutrients can substantially accelerate eutrophication (PSC 2000). Accelerated eutrophication can lead to turbidity, taste and odor problems, growth in nuisance blue-green algae, filter clogging in water intakes, aesthetic impairments, and fish kills due to low dissolved oxygen levels (Saginaw Bay NWI 1994). Nutrient loading from the Saginaw River combined with Saginaw Bay current patterns contribute to accumulation of nutrients and eutrophication in the inner bay (Saginaw Bay NWI 1994). Because the Great Lakes are phosphorus limited, phosphorus loading determines the basic productivity of the water body (PSC 2000). Consequently, phosphorus is the nutrient of greatest concern for the control of eutrophication in Saginaw Bay.

As described by Saginaw Bay NWI (1994), significant reductions in phosphorus loadings to Saginaw Bay were achieved in the late 1970s through WWTP upgrades and Michigan's 1977 limits on phosphorus in laundry detergents (Saginaw Bay NWI 1994). In addition, the decline in the early 1990s may have been related to the initial colonization of Saginaw Bay by zebra mussels, a newly introduced exotic bivalve species that feeds by filtering large amounts of water. By the early 1990s, phosphorus concentrations at the mouth of the Saginaw River and upstream of the City of Saginaw ranged from 0.101 mg/L to 0.149 mg/L.

Nutrients in the river and bay likely originate from agriculture, industrial and municipal wastewater discharges, and urban stormwater runoff. Non-point source contributions of total phosphorus to Saginaw Bay are estimated to represent 80% to 91% of the total loading (Arthur et al. 1996). Agriculture is the predominant non-point source contributor to phosphorus loading. In addition, extensive agricultural use of drainage tiles is thought to increase concentrations of soluble phosphorus in drained water relative to what would be present in surface water runoff.

3.5 Soil Erosion and Sedimentation

As discussed by Saginaw Bay NWI (1994), soil erosion and sedimentation are natural processes that are influenced by human intervention. The RAP for the Saginaw Bay watershed AOC attributes sedimentation to 4 of the 12 beneficial use impairments for the AOC (Saginaw Bay NWI 1994). Arthur et al. (1996) report annual sediment loadings to the Saginaw River basin at 970,000 tons. Based on estimates in Saginaw Bay NWI (1994), agricultural non-point sources account for the majority (88%) of those loads. Forestry practices can also contribute to soil erosion, particularly during grazing and timber harvesting activities. As of 1987, the USDA concluded that only approximately 5% of the commercial forest land in the Saginaw Bay area is actively managed to minimize erosion, leaving 95% of the commercial forest land susceptible to soil erosion, runoff, and flooding. In addition, erosion of stream banks can be a source of sedimentation. Such erosion may be facilitated by the flashy flow characteristics of linear drains throughout the area, combined with periodic disturbance by dredging maintenance activities. Erosion of gravel road beds and stream road crossings may also contribute sediment to watercourses. Soil erosion in urban areas is largely attributable to land under development.

According to Saginaw NWI (1994), effects of soil erosion and sedimentation may include: 1) water temperature changes; 2) aggradation of streambeds and elimination of pools and riffles; 3) alteration of flow rates; 4) reduction in sunlight transmission, which can alter rates of photosynthesis and plant growth; 5) aesthetic impairment and increased hazards for swimming and boating; 6) alteration of visual feeding behaviors of fish, which in turn may affect angling success; 7) absorbed pollutants may be transported with eroded soils and taken up by fish; 8) increased fish mortality through suffocation of fish eggs, benthos, and other food organisms; 9) increased habitat degradation, including loss of fish spawning areas; 10) increased biological oxygen demand of the water from algal growth stimulated by nutrients carried with sediments, which adversely affects fish and other aquatic organisms; 11) increased water treatment costs; 12) increased costs to dredge navigational waterways and roadside ditches; and 13) reduced quality of irrigation water.

3.6 Landfills

Until 1997, MDEQ maintained a record of active and historical solid waste facilities throughout the state, including non-hazardous solid waste landfills and transfer stations.[25] EDR (2007) also reports a number of historical landfills that are located within the Saginaw River floodplain and that are not included in MDEQ's database. Locations of all identified landfills within the floodplains of the USR, LSR-SC, and LSR-BC are listed in Table 3-2 and are illustrated on Figures 3-1a through 3-1c, respectively. Although such facilities are designated for non-hazardous wastes, they may be sources of chemical release due to inadvertent or illegal disposal of inappropriate materials. Because historical landfills were not subject to the same restrictions that apply to the current facilities, historical landfills are also potential sources of chemical releases. The EDR report did not list landfills outside the floodplain or located along other rivers in the Saginaw Bay watershed.

[25] http://www.michigan.gov/deq/0,1607,7-135-3312_4123---,00.html

EDR (2007) identified four active solid waste facilities located within or adjacent to the Saginaw River floodplain. One, operated by General Motors (GM) Corporation, is located within one quarter mile of the LSR-SC floodplain and is classified as Type III Low Hazard Industrial Waste Landfill. A Type III landfill is any landfill that is neither a municipal solid waste landfill nor a hazardous waste landfill. Low hazard industrial wastes are wastes from industrial processes with a low potential for groundwater contamination (MI R. 299.4103[x]). The three remaining active landfills are located within or adjacent to the LSR-BC floodplain. Two of the landfills are classified as Type III Low Hazardous Waste Landfills, while the third is a solid waste transfer facility.

MDEQ's database of historical landfills identified several inactive landfills within or adjacent to the Saginaw River floodplain, of which three were mapped (EDR 2007). One of the mapped historical landfills is located in Saginaw within the USR floodplain. The second mapped historical landfill, the Buena Vista Township landfill, is located in Saginaw within the LSR-SC floodplain. The Buena Vista Township landfill was the subject of a preliminary assessment under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) in the early 1980s. However, the site was not placed on the NPL and no remedial action was required (EDR 2007). The third mapped historical landfill is located in Bay City, immediately adjacent to the LSR-BC floodplain. This historical landfill is located on Dore Industrial Development Incorporation property near river mile 7, which has also been the focus of RCRA corrective action due to contaminated groundwater. EDR (2007) provided no further information regarding the types of waste disposed at the site.

3.7 Hazardous Waste Sites

Hazardous waste sites range from large-scale CERCLA sites on the federal NPL to smaller sites requiring corrective action under RCRA and other properties undertaking voluntary cleanup actions. As compiled by EDR (2007) hazardous waste sites include the following: 1) sites on the federal NPL or proposed for inclusion on the NPL under CERCLA; 2) potential hazardous sites referred to the United States Environmental Protection Agency (USEPA) by states, municipalities, tribes, or private entities under the Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) and those that have been removed or archived from CERCLIS; 3) sites that are or have been subjected to corrective action under the RCRA as listed on the corrective action (CORRACTS) database and on the RCRA Administration Action Tracking System (RAATS) for major violators; and 4) sites currently on the MDEQ's contaminated sites list and those that have been removed from the list. As listed in Table 3-3, a total of 80 hazardous waste sites are mapped in or adjacent to the Saginaw River floodplain, including 1 proposed NPL site, 3 sites within the CERCLIS inventory (including the proposed NPL site), 11 sites that have been removed from the CERCLIS inventory with no further remedial action required, and 11 RCRA corrective action sites. At least an equal number of orphaned sites also exist within or adjacent to the Saginaw River floodplain, but could not be mapped due to insufficient information (EDR 2007). Because little information is provided about the orphan sites, only the mapped sites are summarized below.

The one proposed NPL site is the Bay City Middlegrounds site (Table 3-3, Figure 3-1c), which was proposed for inclusion on the NPL in February 1995; no final decision has been made on listing (EDR 2007). The site is located on Middleground Island in the Saginaw River in Bay City, within LSR-BC. It is an inactive municipal landfill and dredged materials disposal site. Site groundwater and soils are contaminated with PCBs, volatile organic carbons (VOCs) (such as benzene, toluene, ethylbenzene, and xylene), pesticides, phthalates, and other chemicals.[26] Several remedial actions have been completed at the site, including landfill capping and installation of a leachate collection system.[27]

Most of the other mapped hazardous waste sites, within or adjacent to the Saginaw River floodplain, are listed on the MDEQ contaminated sites list (Table 3-3). Among the 69 state hazardous waste sites are 28 inactive sites where no action has been taken to address contamination, 28 sites where remedial or response actions are in progress, and approximately 10 sites where response or remedial actions have been completed (EDR 2007). MDEQ has deleted 12 sites from their contaminated sites list (Table 3-3). Fewer than 20 of the mapped state hazardous waste sites are located within the FEMA 100-year floodplain; the remainder are located within one-quarter of a mile of the FEMA 100-year floodplain (Figures 3-1a through 3-1c). The state hazardous waste sites represent a variety of industries including dry cleaners, scrap metal yards, gas stations, oil terminals, rail yards, and miscellaneous manufacturing facilities (EDR 2007).

The Saginaw River itself has also been the subject of a state-lead consent decree and investigation. The 1998 consent order focused on issues surrounding historical industrial and municipal PCB discharges to the river. The consent decree was signed by MDEQ, the Michigan Attorney General, the U.S. Departments of Interior and Justice, the Saginaw Chippewa Indian Tribe, GM Corporation, and the cities of Saginaw and Bay City. The agreement consisted of sediment removal, acquisition and preservation of lands, restoration of wetlands and fishing habitat, construction and/or enhancement of boat launches, and operation of an environmental learning center. The dredging portion of the agreement called for the removal of approximately

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26 http://www.epa.gov/superfund/sites/npl/nar1450.htm

27 http://www.epa.gov/region5superfund/npl/michigan/MID981092935.htm

345,000 cubic yards of PCB-contaminated sediments, or approximately 90% of the residual PCBs in the lower river. Dredging began in April 2000 and finished in July 2001. Removed sediments were disposed of at a CDF in Saginaw Bay near the mouth of the Saginaw River (PSC 2000). In September of 2003, MDEQ collected sediment samples from the dredged portions of the river as part of a post-dredge monitoring program (Taft 2004). PCB concentrations of all surface sediments (0 in to 6 in below the sediment surface) within the dredged areas were less than the PCB remediation target concentration of 1.0 mg/kg. Therefore, MDEQ concluded that the remediation goal had been achieved (Taft 2004). In addition, the USFWS concluded that the residual risk from the remaining PCB concentrations were not sufficient to warrant additional dredging (USFWS 1999).

3.8 Manufactured Gas Plant Sites

As summarized by the New York State Department of Environmental Conservation,[28] from the early 1800s until the mid-1900s, manufactured gas plants (MGPs) produced much of the gas used in communities throughout the United States. MGPs typically produced gas by burning coal, which generated by-products such as coal tars, sludges, and oils. The by-products frequently contained hazardous substances such as cyanide, heavy metals, and polycyclic aromatic hydrocarbons (PAHs). Most MGPs were closed in the 1950s and 1960s, as natural gas became more common and affordable. However, many of the contaminants commonly associated with the former MGP sites persist. Because they were frequently located in urban settings and adjacent to water bodies, former MGP sites are a common potential source for hazardous materials in the environment and are commonly associated with increased human health and environmental risks.

Based on the EDR report (2007), four former MGP sites are located within or adjacent to the Saginaw River floodplain. These sites are listed on Table 3-3 and are mapped on Figures 3-1a through 3-1c. One former MGP site, owned by the East Saginaw Gas Company, is located along the USR in Saginaw. The former Saginaw River Gas Plant in Zilwaukee is located within the FEMA 100-year LSR-SC floodplain. Two former MGP sites owned by Bay City Gas Company are located within one quarter mile of the FEMA 100-year LSR-BC floodplain in Bay City.

3.9 Permitted Industrial Discharges

[28] http://www.dec.ny.gov/chemical/8430.html

Point source discharges to water bodies are regulated under the NPDES. Under the Clean Water Act, all discharges from point sources to waters of the United States require NPDES permits. Permits stipulate what chemicals can be discharged in what amounts and what monitoring and reporting are required. In Michigan, NPDES permits are granted by MDEQ, under USEPA's supervision.

A total of 73 facilities have permitted discharges in or adjacent to the FEMA 100-year floodplain of the Saginaw River; the majority of permitted dischargers are located within the FEMA 100-year LSR-BC floodplain (Table 3-4). Most of the permitted discharges are for industrial or municipal stormwater sewer systems (EDR 2007). Stormwater or urban runoff contains a variety of pollutants and, according to the USEPA, is one of the major sources of impairment in rivers, lakes, and estuaries (USEPA 2002). Urban runoff contains sediments, bacteria, metals, PAHs, and other toxic chemicals (MacKenzie and Hunter 1979, Davis et al. 2001, Menzie et al. 2002, USEPA 2002, Councell et al. 2004). The six permitted municipal storm sewer systems discharge only stormwater; they are not CSOs (see Section 3.3). There are also eight discharge permits issued for sanitary wastewater from WWTPs (see Section 3.2). Finally, eight of the permitted facilities are classified as major dischargers, as defined by NPDES; four of these are WWTPs. Major facilities are defined as facilities with industrial pretreatment programs and with flows in excess of 1 MGD.[29]

3.10 Spills

Chemical spills may occur during transportation of chemicals, fires, industrial accidents, and illegal dumping. EDR (2007) lists all reported spills or accidental releases in or adjacent to the Saginaw River floodplain from the following four data sources: 1) the Emergency Response Notification System (ERNS), which includes releases of oil or hazardous substances as reported to the National Response Center and/or one of the ten regional USEPA offices; 2) the Hazardous Materials Incident Report System (HMIRS), which includes information on hazardous material spill incidents reported to the U.S. Department of Transportation; 3) the Department of Transportation Office of Pipeline Safety (DOT OPS), which records incidents relating to releases from the nation's oil and natural gas pipelines; and 4) MDEQ's Pollution Emergency Alerting System (PEAS), which contains information related to reported tanker accidents, pipeline breaks, and other releases of reportable quantities of hazardous materials. The ERNS and HMIRS databases include spills reported from 1982 to the present; the DOT OPS information includes data since 1980; and PEAS includes data reported to MDEQ from 1996 to the present.

[29] http://cfpub.epa.gov/npdes/glossary.cfm?program_id=0#M

A total of 203 spill incidents have been reported within or adjacent to the Saginaw River floodplain within the timeframes specified above. These spills include 58 reported releases of oil or hazardous substances from ERNS, 90 hazardous material spill incidents during transportation reported to the Department of Transportation in the HMIRS, 5 pipeline spills reported to the DOT OPS, and 50 incidents reported to the MDEQ under PEAS (Table 3-5; EDR 2007). Although the ERNS and PEAS databases contain similar types of incidents, they do not often overlap. Incidents in both systems range from observed and quantifiable releases of known substances to reports of unknown substances observed in water bodies. The majority of all incidents in HMIRS were reported by two shipping companies (Federal Express and Roadway Package System, now owned by Federal Express) in Saginaw and most are related to small, leaking packages. Finally, all five DOT OPS pipeline spills were related to gas pipe leaks from the early 1980s (EDR 2007). Approximately 70% of the reported spills that could be mapped occurred adjacent to (within one quarter mile of) the FEMA 100-year floodplain, but not within the floodplain (Figures 3-1a through 3-1c).

The incidences above only include spills and releases that have been reported to the relevant agencies. They do not include the unknown number of illegal, unreported releases that have and continue to occur to the river and bay. For example, the databases summarized above do not include the illegal discharge of raw sewage to the Saginaw River in August 1996 by the Bay City WWTP that resulted in the criminal conviction of the former superintendent of the plant in 2001.[30]

3.11 Toxic Release Inventory Sites

The TRI is maintained by USEPA under the Emergency Planning and Community Right to Know Act (EPCRA), in order to facilitate the transfer of information to the public related to the storage, treatment, and disposal of chemicals by operating industrial facilities. EDR lists and maps all facilities within and adjacent to the Saginaw River floodplain reporting to the TRI as of December 2004 (EDR 2007). The TRI includes reported releases to all environmental media (e.g., air, surface water, off-site soil, etc.). Releases are classified as on-site or off-site in TRI. Given the size of the study area, on-site releases to any media have the potential to migrate to the river and bay. For example, discharges to air may be deposited within the watershed or bay. Similarly surface water discharges within the watershed are ultimately conveyed to the river and bay. The EDR results were updated based on the 2005 TRI data available from USEPA.[31]

[30] http://www.epa.gov/region5/orc/enfactions/enfactions2001/week-0501.htm
[31] http://www.epa.gov/tri/

A total of 11 facilities within or adjacent to the Saginaw River floodplain reported non-zero TRI releases in 2005 (Table 3-6). Of these, eight are located within a quarter mile of the FEMA 100-year floodplain. Releases from the Consumers Energy utility plant in Essexville (LSR-BC floodplain) comprise more than 95% of the reported releases from the 11 mapped facilities (Figure 3-1a through 3-1c). Consumers Energy reported on-site releases of acids (hydrochloric, hydrofluoric, and sulfuric acids), dioxins and furans (PCDD/Fs), and metals (including barium, chromium, copper, lead, manganese, mercury, nickel, vanadium, and zinc), among other chemicals. In 2005, hydrochloric acid and barium compounds combined made up over 75% of all releases from this facility, while it was reported that 0.002 pounds, or over 1 gram, of PCDD/Fs was released to the atmosphere.[29] All releases from the Consumers Energy facility were released on-site to the air, surface water, or on-site impoundments.[32] The other 10 facilities reported releasing metals, VOCs, and various other chemicals. The Alchem Aluminum facility in Saginaw was the only facility other than Consumers Energy that reported releases of PCDD/Fs (Table 3-6). In 2005, Alchem reported releasing approximately 0.06 pounds (or approximately 26 grams) of PCDD/Fs to off-site landfills and about a quarter of a gram to the atmosphere (Table 3-6).

3.12 Storage Tanks

Underground and above ground storage tanks (USTs and ASTs) are common sources of spills or inadvertent releases of petroleum products and other hazardous substances to the environment.[33] Storage tanks often contain fuel such as oil, gasoline, or diesel and are widespread and common in an urban landscape. USTs and ASTs are regulated and catalogued by MDEQ under RCRA and the state's storage tank program.[34] EDR (2007) lists USTs and ASTs (including incidents of leaks) within and adjacent to the Saginaw River floodplain as recorded by MDEQ as of March 2007.

As illustrated in Figures 3-1a through 3-1c, EDR mapped almost 200 leaking USTs located within or adjacent to the FEMA 100-year floodplain of the Saginaw River since 1986 (Table 3-7). Many additional incidents could not be mapped and, therefore, were not included in this summary (EDR 2007). In addition, there are over 250 registered USTs and almost 50 registered ASTs within or adjacent to the FEMA 100-year floodplain of the Saginaw River, which are also mapped on Figures 3-1a through 3-1c. The listed USTs and ASTs include both active and removed tanks. Most contain petroleum products. The vast majority of USTs and ASTs are

[32] http://www.epa.gov/tri/
[33] http://www.epa.gov/oust/faqs/faq8.htm
[34] http://www.michigan.gov/deq/0,1607,7-135-3311_4115---,00.html.

located outside of, but within one-quarter mile of the FEMA 100-year floodplain of the Saginaw River, while about 20% are located within the FEMA 100-year floodplain.

3.13 Defense Sites

There is one former Department of Defense site within the FEMA 100-year floodplain. The Saginaw National Guard facility encompasses 26.75 acres along the eastern shore of the river near Zilwaukee in Saginaw County, within the LSR-SC floodplain (Table 3-2, Figure 3-1b, EDR 2007). Public information on this site's history is sparse, but it is believed to have been a target range. According to the Government Accounting Office (GAO) website, the site was eligible for cleanup under a Department of Defense cleanup program.[35] Contaminants typically associated with target ranges include lead, copper, and unexploded ordinances.

[35] http://www.gao.gov/gao-01-1012sp/MI.html

4. SUMMARY OF ENVIRONMENTAL DATA

This section summarizes the environmental data collected from the study area that describe the current conditions within the Saginaw River, its floodplain, and Saginaw Bay. The goal of this section is to provide an understanding of the types of environmental data recently collected from the study area. Therefore, environmental data collected from the past ten years are summarized by environmental medium (i.e., floodplain soil, sediment, surface water, and biota).

4.1 Summary of Previous Investigations

The Saginaw River and Bay have been the focus of sampling and investigation for more than 30 years. However, for the purposes of this CCR, current conditions are assumed to be represented by samples collected during the past ten years. Older data were not considered in this section due to the difficulty of validating older data and resultant increased uncertainty pertaining to analytical and sampling methods. Furthermore, because a central goal of this report is to describe current conditions, data more than a decade old are considered less representative than more recent data of current conditions, particularly in light of the significant sedimentation in the system, as well as dredging for both navigational and remediation purposes.

For this CCR, all publicly available data from state and federal agencies and data collected by The Dow Chemical Company (Dow) and its contractors for all environmental media from the Saginaw River, Bay, and floodplain were compiled. Since 1997, sediment samples from the Saginaw River and Bay have been collected by ACOE, MDEQ, and contractors (CH2MHill and ENVIRON) on behalf of Dow; floodplain soil samples have been collected by MDEQ; surface water chemistry samples have been collected by ACOE and ENVIRON, on behalf of Dow; and biota samples have been collected by MDEQ and contractors on their behalf (Table 4-1). Researchers at Michigan State University have also recently collected biota samples as part of ongoing research in the area, but those data are not yet available. With few exceptions, samples of all media have been collected from all four portions of the study area (the USR, LSR-SC, LSR-BC, and SB).

Throughout this section, PCDD/Fs are presented as 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) toxic equivalent concentrations (TEQs), following the approach described by the World Health Organization (WHO) International Programme on Chemical Safety as part of the 2005 re-evaluation of PCDD/F toxicity (Van den Berg et al. 2006). The cumulative toxicity of PCDD/Fs is evaluated by applying 2,3,7,8-TCDD toxic equivalency factors (TEFs) to the concentrations of each PCDD/F congener and each dioxin-like PCB congener. The TEFs applied herein relate the mammalian toxicity of 17 PCDD/F congeners and 12 dioxin-like PCB congeners to that of 2,3,7,8-TCDD as determined at a 2005 WHO workshop (Van den Berg et al. 2006). The TEFs are, therefore, referred to as "2005 WHO TEFs."[36] Summing the TEF-adjusted concentrations yields the TEQ concentration. In cases where other TEF schemes were originally applied to analytical data, TEQs are recalculated in this report based on the 2005 WHO TEFs for mammals, so that all TEQs reflect the same TEF scheme. Thus, even data collected prior to 2005 are reported as TEQs based on the 2005 WHO TEFs for mammalian toxicity. TEQs for PCDD/Fs were calculated separately from TEQs for dioxin-like PCBs when concentrations were available for the relevant PCB congeners.

4.2 Environmental Chemistry Data for Soil

Environmental chemistry data for soil contamination in the Saginaw River FEMA 100-year floodplain is derived from several years of data collected by MDEQ as part of the phased Tittabawassee/Saginaw River floodplain sampling.[37] Although floodplain soil samples have been collected since at least 1992, those collected since 1997 are assumed to be most representative of current conditions and are discussed below. All soil data discussed below are mapped in Figures 4-1 and 4-2. Figure 4-1 illustrates the distribution of average concentrations of PCDD/F TEQs from recent surface soil samples (0 in to 6 in bgs) and Figure 4-2 presents the maximum TEQ concentrations for all depths.

Floodplain soil samples have been collected from a variety of land use types included in the 2001 National Land-Use Dataset.[38] Almost half the samples (40%) were collected from areas classified as low-density, developed, 30% were collected from developed open-spaces, and 10% were collected from emergent herbaceous wetlands. The remaining 20% of floodplain soil samples were collected from a variety of land uses including barren lands, woody wetlands, medium intensity developed, forests, pastures, and shrub/scrub.

As discussed in greater detail in the following subsections, floodplain soil concentrations of PCDD/Fs were highest in the USR and were at similar lower concentrations downstream. Concentrations of metals in soil were similar throughout the Saginaw River and Saginaw Bay floodplain. PCBs were detected in most floodplain soil samples and PCB concentrations were highest in the USR floodplain, intermediate in the LSR-BC floodplain and lowest in the LSR-SC and SB floodplain samples. Pesticides, semivolatile organic compounds (SVOCs) and volatile

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[36] http://www.who.int/ipcs/assessment/tef_update/en/
[37] http://www.michigan.gov/deq/0,1607,7-135-3311_4109_9846_9847-43808--,00.html
[38] http://www.mrlc.gov/nlcd_update.asp

organic compounds (VOCs) were detected infrequently in floodplain soil samples and did not exhibit any clear spatial patterns.

4.2.1 Upper Saginaw River Soil Data

MDEQ collected soil samples from ten locations along the entire length of the USR floodplain in 2000 and 2004. The soil samples collected in 2000 were surface (0 in to 3 in bgs) grab samples; they were analyzed for PCDD/Fs. The soil samples collected in 2004 were cores (to 15 in bgs). Multiple depths from each core were analyzed for PCDD/Fs, PCBs, metals, pesticides, VOCs, SVOCs, and hydrocarbons (Table 4-1). PCDD/Fs were detected in all samples, with TEQ concentrations ranging from 0.4 nanograms per kilogram (ng/kg)[39] to 5,700 ng/kg dry weight (dw) and averaging 760 ng/kg. The detected chemical concentrations from all recent USR floodplain samples are summarized in Table 4-2a.

Metals were only analyzed in the locations sampled in 2004 by MDEQ within the USR FEMA 100-year floodplain. With the exceptions of cobalt, lithium, and nickel, all metals were detected in the majority of samples. The highest concentrations of metals were associated with naturally occurring elements, such as aluminum, calcium, iron, and magnesium. PCBs were widely detected in floodplain soils. The tetrachlorinated and pentachlorinated biphenyl homologue groups were present at somewhat higher concentrations (i.e., greater than 5,000 µg/kg) than either the less chlorinated or more chlorinated PCBs (Table 4-2a). Total PCB homologue concentrations ranged widely from 1.1 µg/kg to 25,000 µg/kg and averaged 4,000 µg/kg while the dioxin-like PCB TEQ concentrations ranged from 0.2 ng/kg to 930 ng/kg and averaged 170 ng/kg. Finally, dichlorodiphenyltrichloroethane (DDT) and its metabolites and SVOCs were less prevalent, in that they were generally detected in fewer than half of the soil samples in which they were analyzed. The detected SVOCs included PAHs and phthalates; they were generally present at concentrations less than 1.0 mg/kg.

4.2.2 Lower Saginaw River (Saginaw County) Soil Data

MDEQ collected soil core samples (to a depth of 15 in bgs) from seven locations along the entire length of the LSR-SC floodplain in 2002 and 2004. All samples were analyzed for PCDD/Fs and PCBs at multiple depth increments. In addition, the 2004 samples were also analyzed for metals, VOCs, SVOCs, and hydrocarbons (Table 4-1). As in the upstream reach, PCDD/F TEQs were detected at all locations but concentrations in LSR-SC were

[39] Equivalent to parts per trillion or ppt

generally an order of magnitude lower than in USR. The detected chemical concentrations from all recent LSR-SC floodplain samples are summarized in Table 4-2b.

The PCDD/F detection frequency was more variable in the LSR-SC soil samples than in the USR. The range of PCDD/F TEQs was also narrower in the LSR-SC than in the USR; TEQ concentrations ranged from 0.38 ng/kg to 140 ng/kg, with a mean of 25 ng/kg (Table 4-2b). While a larger number of metals were detected in the LSR-SC soil samples than in the USR soil samples, concentration patterns were similar between the two reaches; that is, naturally occurring elements (e.g., aluminum, calcium, iron, and magnesium) were present at the highest concentrations in soil. Like PCDD/Fs, PCBs were detected less frequently in the LSR-SC soil samples than in the USR. Again, the tetrachlorinated and pentachlorinated biphenyl homologue groups were present at higher concentrations than either less chlorinated or more chlorinated homologues, but total PCB homologue concentrations in LSR-SC floodplain soil did not exceed 70 µg/kg, which is well below the maximum total PCB concentration from the USR. The dioxin-like PCBs TEQs ranged from 0.10 ng/kg to 1.5 ng/kg, with a mean of 0.27 ng/kg. SVOCs and VOCs were infrequently detected in LSR-SC floodplain soil. Detected SVOCs were again comprised of PAHs and phthalates, while the only detected VOC was 1,4-dichlorobenzene.

4.2.3 Lower Saginaw River (Bay County) Soil Data

MDEQ collected soil samples from 12 locations along the entire 11 mile reach of the LSR-BC floodplain; all but one of those locations were sampled in 2004 (Table 4-1). The soil sample collected in 2002 included surface soil to a depth of 2 in, while the samples collected in 2004 included soil to a depth of 15 in bgs. Multiple depth increments were sub-sampled from the 2004 samples for chemical analysis. All soil samples were analyzed for PCDD/Fs and PCBs. Samples collected in 2004 were also analyzed for metals, pesticides, VOCs, SVOCs, and hydrocarbons. The detection frequency and concentration range of PCDD/Fs in the LSR-BC were similar to the LSR-SC. Concentrations of TEQs ranged from 0.04 ng/kg to 600 ng/kg, with a mean of 38 ng/kg. The detected chemical concentrations for all recent soil samples from the LSR-BC floodplain are summarized in Table 4-2c.

The detection frequencies for PCDD/Fs in the LSR-BC floodplain soil samples were similar to those from the upstream reaches. Detection frequencies were not as high as in USR, but most congeners were detected in most of the samples. Concentrations of metals in the LSR-BC floodplain soil show a similar pattern to the USR and LSR-SC data. Most metals were detected in most soil samples and naturally occurring elements generally had the highest concentrations. PCBs were detected more frequently in the LSR-BC floodplain soil samples than in the LSR-SC samples. Maximum PCB concentrations in the LSR-BC samples were also higher than those from the LSR-SC, but they were not as high as in the USR floodplain. Total PCB homologues ranged from 0.059 µg/kg to 3,400 µg/kg, and the tetrachlorinated, pentachlorinated, and hexachlorinated homologues were present at higher concentrations in the LSR-BC floodplain than other homologues. The dioxin-like PCBs TEQ concentrations ranged from 0.12 ng/kg to 200 ng/kg, with a mean of 15 ng/kg. Finally, SVOCs and VOCs were infrequently detected in the LSR-BC soil samples. Only diethyl phthalate was detected in the majority of samples in which it was analyzed. The remaining detected SVOCs were another phthalate and PAHs, while toluene was the only detected VOC (Table 4-2c).

4.2.4 Saginaw Bay Soil Data

MDEQ has collected floodplain soil samples from seven beaches along SB within the FEMA 100-year floodplain (Table 4-1) and were categorized as within the SB floodplain rather than the LSR-BC floodplain (Figures 4-1 and 4-2). One of the samples was collected in 2002 and was analyzed for PCDD/Fs and PCBs. The remaining six samples were collected in 2004 and were analyzed for PCDD/Fs, metals, PCBs, pesticides, SVOCs, VOCs, and hydrocarbons. The sample collected in 2002 and four of the samples collected in 2004 included only surface soil. The sample collected in 2002 included the top 2 in, while the surface soil samples collected in 2004 included the top 1 in. The other two 2004 samples were soil cores to a depth of 15 in bgs and were sub-sampled at three depth increments. Concentrations of PCDD/F TEQs from the seven soil sample locations in SB were similar to those in the LSR-BC floodplain. Concentrations ranged from 0.11 ng/kg to 160 ng/kg, with a mean of 20 ng/kg. The detected chemical concentrations from the three SB floodplain soil samples are summarized in the Table 4-2d.

The seven beaches sampled within the SB floodplain demonstrated similar patterns to the other floodplain soil samples. PCDD/F detection frequencies were similar to those in the LSR-SC and LSR-BC floodplain samples. The range of concentrations of PCDD/F TEQs was similar to the range from the LSR-SC (Table 4-2d). Detection frequencies for metals and PCBs from the SB beach floodplain samples were similar to the other floodplain samples, although maximum concentrations were consistently lower in the SB samples than in any of the other floodplain areas (Table 4-2a-d). For example, the maximum total PCB homologue concentration of 25 µg/kg was two orders of magnitude lower than concentrations observed in samples from the LSR-BC floodplain soil. However, the concentration of dioxin-like PCBs TEQs ranged from 0.12 ng/kg to 1.9 ng/kg, with a mean of 0.48 ng/kg, similar to the values reported for the LSR-SC. Finally, several SVOCs and VOCs were detected in the SB floodplain soil samples, but the low sample size (n = 2) makes comparison to the other floodplain areas uncertain.

4.3 Environmental Chemistry for Data

The Saginaw River and Bay have been the focus of sediment investigations for over 30 years. This discussion on environmental data for sediment is based on samples collected within the past ten years. As such, this summary includes data collected by MDEQ, ACOE, and Dow contractors (Table 4-1). Figures 4-1 and 4-2 present the average concentrations of PCDD/F TEQs from recent surface sediment samples (0 in to 6 in bgs) and the maximum concentrations of PCDD/F TEQs from all sampled depths, respectively, in the Saginaw River and Bay. Because of the targeted removal of high PCB concentration sediment from the LSR-BC in 2000 and 2001, only sediment data collected since the completion of dredging are considered representative of current conditions in the LSR-BC. Therefore, due to the potential for disturbance of sediment adjacent to the dredged area, all sediment data from the LSR-BC were constrained to those collected since dredging was completed in 2001.

As discussed in greater detail in the following subsections, maximum and average sediment PCDD/F TEQ concentrations were highest in the USR and decreased in each downstream reach. Metals concentrations were more consistent throughout the river and bay and exhibited similar patterns to the soil data. Sediment PCB concentrations exhibited the same downstream pattern as the PCDD/F concentrations. Highest concentrations were located in the USR and progressively lower concentrations were observed moving downstream and into SB. However, small sample sizes in USR and LSR-BC render any conclusions about spatial patterns in sediment PCB concentrations uncertain. As with the soil data, pesticides, SVOCs, and VOCs were infrequently detected in sediment samples from the river and bay.

4.3.1 Upper Saginaw River Sediment Data

Sediment samples have been collected from 28 sample locations along the entire five mile reach of the USR as part of four separate studies conducted since 2004 (Table 4-1). ACOE collected surface sediment from two locations north of the Interstate 675 bridge in July of 2004. Samples collected by ACOE were analyzed for PCDD/Fs and sediment grain size. In the fall of 2004, MDEQ collected surface sediment from three locations in the USR: one near the confluence of the Tittabawassee and two north of the Ojibway Turning Basin. The 2004 MDEQ samples were analyzed for PCDD/Fs, metals, PCBs (one was analyzed for congeners and homologues and two were analyzed for Aroclors[40]), pesticides, VOCs, SVOCs, hydrocarbons, and grain size. Those samples were collected as part of MDEQ's evaluation of dioxin-like toxicity in the Saginaw Bay watershed for the Great Lakes National Program Office (GLNPO; MDEQ 2006). CH2MHill collected sediment cores to a depth of up to 5.8 ft bgs from 15 locations along the entire five mile reach of the USR in December 2004 and analyzed them for PCDD/Fs, metals, PCB Aroclors, SVOCs, and TOC (CH2MHill 2005). Finally, ENVIRON collected sediment cores to a depth of up to 19 ft bgs from eight locations immediately upstream of, within and immediately downstream of the Ojibway Turning Basin in the fall of 2006. Those samples were analyzed for PCDD/Fs, TOC, and grain size. PCDD/Fs were detected in most sediment samples and concentrations of PCDD/F TEQs ranged from 0.3 ng/kg to 12,000 ng/kg (dw) and averaged 1,000 ng/kg in the USR. The concentrations of detected chemicals in sediments of the USR are summarized in Table 4-3a.

PCDD/Fs (with the exception of one congener) were detected in the majority of sediment samples from the USR (Table 4-3a). Most metals were frequently detected in sediment samples. Only mercury and thallium were not detected in the majority of samples (Table 4-3a). The highest concentrations of metals in USR sediment samples were associated with naturally occurring elements (aluminum, calcium, iron, and magnesium). Several PCB congeners were detected in the one sediment sample for which they were analyzed, but no Aroclors were detected in any of the 32 sediment samples in the USR for which they were analyzed. The total PCB homologue concentration in the one sample analyzed for homologues was 90,000 µg/kg and the dioxin-like PCBs TEQ was 0.49 ng/kg. The highest concentrations of PCBs were for the dichlorinated, trichlorinated, and tetrachlorinated homologue groups (Table 4-3a). With the exception of benzo(a)pyrene, several SVOCs were detected in up to half of the USR sediment samples. Benzo(a)pyrene was detected in more than 80% of the USR sediment samples. The detected SVOCs included 17 PAHs and a phthalate. No pesticides or VOCs were detected in USR sediment samples.

4.3.2 Lower Saginaw River (Saginaw County) Sediment Data

Surface sediment samples have been collected from 51 locations in the LSR-SC since 1997 (Table 4-1). ACOE collected surface sediment samples from eight locations along the

[40] There is some uncertainty in matching PCB Aroclors mixtures from environmental media to Aroclor standards. Results may vary among laboratories.

entire six mile reach of LSR-SC in August of 1999 and analyzed them for PCDD/Fs, metals, PCBs (Aroclors), pesticides, TOC, and grain size. ACOE also collected surface sediment samples from another 32 locations along the entire six mile reach of the LSR-SC in July of 2004; four locations were within the Crow Island State Game area just north of Zilwaukee, and the remaining 28 locations were along the entire length of the LSR-SC. Those samples were analyzed for PCDD/Fs and sediment grain size. Finally, in the fall of 2004, MDEQ collected surface sediment samples from eleven locations along the entire six mile reach of LSR-SC as part of their dioxin evaluation for the GLNPO (MDEQ 2006). Sediment samples for the program were analyzed for PCDD/Fs, metals, PCBs (five samples for 12 coplanar congeners and homologues and seven samples for Aroclors), pesticides, VOCs, SVOCs, hydrocarbons, and grain size. Although PCDD/Fs were detected in the majority of sediment samples, the range of TEQs from the LSR-SC was slightly lower than in the USR. Concentrations of TEQs in the LSR-SC ranged from 0.6 ng/kg to 6,200 ng/kg, and averaged 440 ng/kg. The detected chemical concentrations from all recent LSR-SC sediment samples are summarized in Table 4-3b.

As described above, the detection frequencies for PCDD/Fs were similar in the LSR-SC sediment samples to those from the USR, although TEQ concentrations were somewhat lower in the LSR-SC (Tables 4-3a and b). Metals analyses were only conducted on three of the sediment samples from the LSR-SC, but all metals except beryllium and mercury were detected in all sediment samples. Metals concentration ranges were similar to those in the USR sediment samples. Coplanar PCBs and homologues were analyzed in five sediment samples and PCB Aroclors were analyzed for in ten sediment samples. Nine of the coplanar PCBs were detected in the majority of samples, while no PCB Aroclors were detected in any of the sediment samples from the LSR-SC. Total PCBs (as homologues) ranged from 0.9 µg/kg to 24,000 µg/kg, with an average of 11,000 µg/kg. The highest PCB sediment concentrations were for the tetrachlorinated, pentachlorinated, and dichlorinated homologue groups (Table 4-3b). Dioxin-like PCB TEQs ranged from 0.05 ng/kg to 400 ng/kg, with an average of 220 ng/kg. No pesticides, SVOCs, or VOCs were detected in any of the sediment samples from LSR-SC for which they were analyzed.

4.3.3 Lower Saginaw River (Bay County) Sediment Data

Due to the targeted dredging of PCB-contaminated sediments in the LSR-BC that was completed in 2001, sediment data collected prior to the completion of dredging are largely excluded from this discussion. However, because so few (n = 4) sediment samples were collected between 1997 and 2001, Figures 4-1 and 4-2 present all results from 1997 to 2007. Since 2001, sediment samples have been collected from 44 locations in the LSR-BC. As described in Section 3.7, MDEQ collected sediment cores to a depth of 6.5 ft bgs from 12 locations within a 2.5 mile reach of LSR-BC in Essexville and Bay City in September of 2003 and analyzed three depth increments for PCBs (Aroclors) and grain size (Taft 2004) as part of the post-dredge monitoring program. Only those Aroclors that were detected were reported (non-detects were not reported). In July of 2004, ACOE collected surface sediment samples from 20 locations along the entire 11-mile reach of LSR-BC and analyzed them for PCDD/Fs and grain size. Finally, MDEQ collected surface sediment from 12 locations along the entire 11-mile reach of LSR-BC in the fall of 2004 and analyzed most for PCDD/Fs, metals, PCBs (two for coplanar PCBs and nine for Aroclors), pesticides, VOCs, SVOCs, hydrocarbons, and grain size (MDEQ 2006). Values for Aroclors that were not detected were reported as non-detects. The range of concentrations of PCDD/F TEQs in LSR-BC sediments was lower than the ranges from both upstream reaches. The average concentration of PCDD/F TEQs was 140 ng/kg, while concentrations ranged from 2.2 ng/kg to 440 ng/kg. Table 4-3c summarizes the detected chemical concentrations from LSR-BC sediments.

Detection frequencies for PCDD/Fs were similar in LSR-BC sediments as in the upstream reaches of the Saginaw River. Most congeners were detected in the majority of sediment samples (Table 4-3c). Most metals were detected in all samples of LSR-BC sediments; the only exceptions were cadmium, mercury, selenium, and silver (Table 4-3c). Metals concentrations were similar to those in upstream reaches, but maximum concentrations of total chromium, lead, and zinc in sediment exceeded upstream maximum concentrations by at least a factor of three. All but one of the coplanar PCBs were detected in both sediment samples from the LSR-BC. The detection frequencies of PCB Aroclors were more variable; Aroclor 1242 was detected in the majority of samples, but Aroclors 1254 and 1260 were not. As such, the Aroclor 1242 mixture made up the majority of the PCBs in the samples for which it was analyzed. The maximum concentration of Aroclor 1242 was 5,100 µg/kg in LSR-BC sediments. The highest PCB homologue concentrations in the two samples for which they were analyzed were for the trichlorinated and tetrachlorinated biphenyl homologue groups. Concentrations of dioxin-like PCB TEQs in LSR-BC sediments ranged from 0.29 ng/kg to 2.5 ng/kg, and averaged 1.4 ng/kg. Several SVOCs and one VOC (1,4-dichlorobenzene) were detected in few of the sediment samples for which they were analyzed. Detected SVOCs included eight PAHs and three phthalates. The maximum concentrations of SVOCs in the LSR-BC samples were generally an order of magnitude lower than the maximum concentrations from the USR.

4.3.4 Saginaw Bay Sediment Data

Sediment samples have been collected from 16 locations in Saginaw Bay since 1997. ACOE collected surface sediment samples from six locations in the bay in August 1999 and analyzed them for PCDD/Fs, metals, PCBs (Aroclors), pesticides, TOC, and grain size. In the fall of 2004, MDEQ collected surface sediment samples from ten locations in Saginaw Bay as part of the GLNPO Saginaw Bay watershed dioxin evaluation (MDEQ 2006). Sediment samples were analyzed for PCDD/Fs, metals, PCBs (five for coplanar PCB congeners and six for Aroclors), pesticides, VOCs, SVOCs, hydrocarbons, and grain size. The range of concentrations of PCDD/F TEQs in SB sediment samples was less than those from all reaches of the Saginaw River. The average concentration of PCDD/F TEQs in sediment was 61 ng/kg, while concentrations ranged from 0.16 ng/kg to 150 ng/kg. The detected chemicals from recent sediment sampling in SB are summarized in Table 4-3d.

Consistent with the pattern from all reaches of the Saginaw River, most PCDD/Fs were detected in the majority of recent sediment samples from SB (Table 4-3d). With the exception of selenium, all metals were detected in the majority of sediment samples for which they were analyzed. For most metals, the range of sediment concentrations in SB were similar to those in the USR and LSR-SC (Tables 4-3a,b,d). Most coplanar PCBs were detected in most of the sediment samples, but PCBs as Aroclors were not detected above the minimum detection limits ranging from 120 µg/kg to 230 µg/kg in any of the twelve locations for which they were analyzed. The trichlorinated, tetrachlorinated, and pentachlorinated PCB homologue groups were present in SB sediment at higher concentrations than either more or less chlorinated homologues. However, total PCB homologue concentrations in SB were several orders of magnitude lower than those in sediment collected from Saginaw River; they ranged from 3.8 µg/kg to 17.0 µg/kg and averaged 9.8 µg/kg in SB sediments. Dioxin-like PCBs TEQs in SB sediment samples were more similar to but still relatively lower than TEQs reported in the river. The PCB TEQs ranged from 0.24 ng/kg to 0.63 ng/kg and averaged 0.48 ng/kg. Three SVOCs were each detected in one of the SB sediment samples and two dodecanoic acid compounds were also detected in SB sediment samples.

4.4 Environmental Chemistry Data for Surface Water

As discussed in Section 3.5, Saginaw Bay has been classified as eutrophic since at least the 1960s. As such, much of the surface water analysis in the Saginaw River has focused on nutrients, dissolved oxygen, and bacteria. Relatively few studies have addressed the presence of other chemicals in surface water. All relevant surface water quality monitoring data collected by

MDEQ from Saginaw River and Bay were downloaded from USEPA's STORET database.[41] Monitoring data were obtained for 20 stations in Saginaw Bay and one in the Saginaw River approximately two miles upstream of the river's mouth. Typically, MDEQ monitoring samples are analyzed for nutrients and conventional parameters, such as temperature and dissolved oxygen. Some samples from the Saginaw River station were also analyzed for PCB congeners. Due to apparent inconsistencies, and hence, concerns about data quality in the reported concentrations and units of mercury detected in Saginaw River and Bay surface water samples, mercury data from the STORET database were excluded from this analysis. In addition to the MDEQ monitoring data, this summary describes data collected from two sampling events from the past ten years that focused on chemicals in surface water. The first surface water sampling event was conducted by the ACOE in August of 1999 and focused on mercury. The second surface water sampling event was conducted by ENVIRON and focused on the presence of PCDD/Fs associated with suspended solids in the water column. ACOE collected water from one meter above the sediment surface at 32 locations in the LSR-SC, LSR-BC, and SB. Mercury was never detected in the ACOE samples at a reported detection limit of 0.00002 mg/L (Table 4-1). Consequently, the ACOE results are not further discussed in this section. None of the sampling programs summarized in this section included samples collected from within the USR.

There are relatively few data on chemical concentrations in surface water in Saginaw River and Bay. The only PCDD/F data for surface water were collected from the LSR-SC, where PCDD/Fs were detected in the suspended solids during both dry and wet weather events. Metals concentrations have been measured in samples from LSR-BC and SB. The patterns of metals concentration are similar in both reaches, but concentrations in SB were consistently lower than in LSR-BC. PCBs were measured on several dates at one station in LSR-BC and detected PCB concentrations varied by a factor of 20. Pesticides (DDT and chlordane) were measured at the LSR-BC station and were infrequently detected.

4.4.1 Lower Saginaw River (Saginaw County) Surface Water Data

ENVIRON is conducting an assessment of sediment dynamics in the Sixth Street Turning Basin in Saginaw, MI on behalf of Dow. One aspect of this study involved the collection of surface water from 23 locations in the Turning Basin during a period of dry weather in November of 2006 and during a period of wet weather in March of 2007. The samples were analyzed for TOC, suspended solids, and PCDD/Fs affiliated with the

[41] http://www.epa.gov/storet/dbtop.html.

suspended solids. The concentrations of PCDD/F TEQs associated with suspended solids in the LSR-SC ranged from 2.0 ng/kg to 3,900 ng/kg, and averaged 180 ng/kg. The PCDD/Fs were measured relative to the suspended solids in the water column. Therefore, they are presented in units of ng/kg of suspended solids, rather than ng/L of water. The detected chemical concentrations from the recent surface water sampling in the LSR-SC are summarized in Table 4-4a.

4.4.2 Lower Saginaw River (Bay County) Surface Water Data

The MDEQ water quality monitoring station for the Saginaw River is located adjacent to Main Street in Essexville, MI. Between June of 1998 and November of 2005, MDEQ collected over 70 surface water samples from this location and analyzed them for metals, nutrients, and conventional parameters, such as temperature, turbidity, and alkalinity. In addition, many of the water samples were analyzed for approximately 100 PCB congeners and two pesticides (Table 4-1). All MDEQ water quality monitoring data from the monitoring station in the LSR-BC were obtained from the USEPA STORET database. The detected chemicals from the recent MDEQ surface water monitoring in LSR-BC are summarized in Table 4-4b.

All metals were detected in all surface water samples collected by MDEQ from LSR-BC (Table 4-4b). PCB congeners were detected in surface water on all 23 dates for which they were sampled. The MDEQ samples were not analyzed for a sufficient number of PCB congeners to calculate the total PCB concentration in each sample. However, the concentration of all PCBs analyzed (approximately 100 congeners) ranged from 0.002 µg/L to 0.039 µg/L, with a mean partial PCB sum of 0.015 µg/L (Table 4-4b). Chlordane and DDT were detected in approximately 30% of the surface water samples in which they were analyzed. Maximum detected concentrations of chlordane and DDT were 0.2 µg/L and 1.7 µg/L, respectively. Finally, nitrogen and phosphorus compounds were detected in all surface water samples. Maximum inorganic nitrogen concentrations as nitrate and ammonia were 4.5 mg/L and 0.5 mg/L, respectively, and the maximum inorganic phosphorus concentration as orthophosphate was 0.7 mg/L.

4.4.3 Saginaw Bay Surface Water Data

MDEQ maintains 20 water quality monitoring stations throughout SB. MDEQ has collected surface water samples within SB on 270 dates between 1998 and 2006 and analyzed them for metals, nutrients, bacteria (i.e., *Escherchia spp*, such as *E. coli*), as well as conventional parameters, such as temperature, turbidity, and alkalinity (Table 4-1). All recent MDEQ surface water data from SB were obtained from the USEPA STORET database.[42] The detected chemicals from recent SB surface samples are summarized in Table 4-4c.

Metals were detected less frequently in the SB surface water samples than in the LSR-BC samples (Tables 4-4b and 4-4c). In addition, the maximum detected concentrations of metals were consistently lower in the SB samples than in the LSR-BC samples. Concentrations of nitrogen and phosphorus demonstrated a similar pattern. Compared to Saginaw River, nutrients were detected less frequently in SB samples and maximum concentrations were lower. The decrease in nutrient concentrations in SB and the range of concentrations of chlorophyll, turbidity, and dissolved oxygen (Table 4-4c) are consistent with previous work indicating that the Saginaw River basin is a primary source of nutrients to Saginaw Bay (Arthur et al. 1996).

4.5 Environmental Chemistry Data for Biota

This subsection describes available data on chemical concentrations in benthic invertebrates, fish, mammals, and birds in the USR, LSR-SC, LSR-BC, and SB. Extensive data on chemicals in biota have been collected and published over the last three decades, but in order to focus the presentation on current and recent conditions, with only a few exceptions, data from only the last ten years are discussed below. Dow has funded considerable research by Michigan State University related to chemical exposure to a variety of biota (frogs, insects, birds, mink, small mammals, and plants) in the Tittabawassee River and Saginaw River basin; however, because data collected from the Saginaw River are not yet validated, they are not presented here. Because this CCR focuses on the Saginaw River and Bay, data collected by Michigan State University in the Tittabawassee River also are not presented here.

4.5.1 Chemicals in Epibenthic and Benthic Invertebrates

There are few recent studies describing chemical concentrations in epibenthic and benthic invertebrates of Saginaw River and Bay. The USEPA GLNPO conducted invertebrate toxicity tests with sediment from the Saginaw River as part of their Assessment and Remediation of Contaminated Sediments program from 1988 through 1994.[43] However, invertebrate tissue chemistry data were not collected and the toxicity test results are not incorporated in this CCR as they are not likely to represent current conditions.

[42] http://www.epa.gov/storet/dbtop.html

Two studies were identified that documented ranges of chemical concentrations in invertebrates from the Saginaw Bay and River. Both studies were conducted more than ten years ago, but given the paucity of data on invertebrates, they are both included in this summary. In 1987, USEPA conducted a caged unionid clam (*Lampsilis radiata siliquoidea Barnes*) study evaluating if contaminants were being transported through the dike walls of CDF in SB and concluded that PCB concentrations in clams within the CDF were higher than PCB concentrations in clams outside the CDF (USEPA 1994). In addition, PCB concentrations in clams did not increase following disposal of dredged materials in the CDF. Froese et al. (1998) conducted a tree swallow (*Tachycineta bicolor*) study to evaluate the potential for bioaccumulation of PCBs from sediments that included invertebrates from the Saginaw River. They concluded that the concentration of dioxin-like PCBs in invertebrates from the Saginaw River were below the threshold for effects on tree swallows.

USEPA's study of PCB transport from the dredge disposal site was conducted in 1987 using native clams caged inside and outside of the CDF dike in SB (USEPA 1994). The study was conducted prior to and following dredge disposal in the CDF. Prior to dredge disposal, three sites were monitored, including one located within the dike, one outside the dike, and one reference site. After dredge disposal, eight sites were monitored, including three located within the dike, three outside the dike, and two reference stations. During each phase, 60 to 65 clams were deployed in cages for 10-day exposure periods and were then collected and analyzed for total PCBs (USEPA 1994).

Prior to dredging, the mean total PCB concentrations were higher in the clams deployed within the dike (103.7 μg/kg wet weight [ww]) than in clams deployed outside of the dike (37.3 μg/kg ww). Following the disposal of dredged materials, concentrations of PCBs in clams were generally lower than before disposal. The concentrations of total PCBs in clams from the sites outside of the dike were, again, lower (17.3 μg/kg to 21.0 μg/kg ww) than those from within the dike (34.0 μg/kg to 55.0 μg/kg ww; USEPA 1994).

In their tree swallow exposure study, Froese et al. (1998) evaluated relative concentrations of individual congeners, as well as total PCB concentrations, in different trophic compartments to determine whether toxic potentials of PCB mixtures change as a function of trophic level. They measured concentrations of PCBs in sediment, emergent aquatic insects (primarily chironomidae), and eggs and nestlings of tree swallows

[43] http://www.epa.gov/glnpo/arcs/index.html

collected in 1992 from three sites in the lower Saginaw River. The mean concentration of total PCBs in the nine invertebrate samples from the Saginaw River was 19 μg/kg (lipid). As stated above, Froese et al. (1998) concluded that the concentrations of dioxin-like PCBs in the sediments should be below the threshold for adverse effects on tree swallows.

4.5.2 Chemicals in Fish

MDEQ has collected and analyzed fish tissue as part of the Fish Contaminant Monitoring Program (FCMP) for more than 20 years. Under this program, three types of samples have been collected: edible portions (i.e., fillets) from several resident (free swimming) sportfish species, whole body samples of several resident fish species, and composite whole body samples of caged channel catfish deployed in the river or bay for 28 days (Table 4-1). The edible portion samples are collected to support MDCH's determination of fish consumption advisories for sportfish and Michigan's Department of Agriculture regulation of sales of commercial catch. The whole body samples are collected in support of MDEQ's efforts to identify spatial and temporal trends in water quality throughout Michigan and to evaluate whether chemical contamination in aquatic environment is being reduced. The caged fish studies are used to identify sources of bioaccumulative chemicals and to identify spatial trends in chemical concentrations (MDEQ 2007a). Since 1997, resident fish tissue samples have been collected from one site in the LSR-BC and four sites in SB, and caged catfish studies have been conducted at one site in the LSR-SC, six sites in the LSR-BC, and one site in SB. Target analytes have included: PCDD/Fs, total mercury, PCB congeners and Aroclors, pesticides and several other organic chemicals. Tables 4-5a through 4-5c list the locations, sample types, species, and results of FCMP sampling conducted since 1997 in LSR-SC, LSR-BC, and SB, respectively, based on data provided by Mr. Joseph Bohr, MDEQ. No fish tissue data from USR are available.

The only type of fish tissue sample that has been collected across multiple reaches of the Saginaw River and Bay are the whole body, caged channel catfish samples (Table 4-1). While concentrations of PCDD/F TEQs, total mercury concentrations, and PCB TEQ concentrations varied little between the LSR-SC, LSR-BC, and SB, total PCB congener concentrations were more variable. The highest PCB concentrations were reported in the LSR-BC, where the majority of samples have been collected. Data were available for less then half of all PCB congeners, but the range of the partial sum of PCB congeners from the composite whole body samples from LSR-SC were lower than those from the downstream reach and concentrations from the SB composites were more similar to those from the LSR-BC.

Tissue concentrations in resident fish samples exhibited relatively high variability within and between the species collected. Concentrations for organic chemicals, such as PCDD/Fs and PCBs, tended to be higher in the resident whole body fish samples than in the fillet samples. Total mercury concentrations tended to be highest in the resident walleye samples (both whole body and fillet). The average concentrations and ranges for all detected chemicals are summarized in the following subsections and a statistical analysis of fish tissue PCDD/F concentrations is presented in Section 4.5.2.4.

4.5.2.1 Recent Fish Tissue Data for Lower Saginaw River (Saginaw County)

The only fish tissue data from the Saginaw County reach of the Lower Saginaw River were caged fish studies conducted in 1998 and 2002 to evaluate chemical uptake by fish. A total of 64 channel catfish were placed in cages at the Zilwaukee Bridge. Following 28 days in the river, the whole body samples were analyzed for a variety of chemicals including PCDD/Fs, total mercury, PCBs (Aroclors and congeners), pesticides (e.g., DDT and its metabolites), and other organic compounds. Concentrations of PCDD/F TEQs were fairly consistent across composite samples, as they ranged from 1.7 ng/kg (ww) to 3.3 ng/kg and averaged 2.4 ng/kg. There was also little variability in total mercury and PCB concentrations, with all detected concentrations between 0.01 mg/kg and 0.02 mg/kg for total mercury and 3.0 µg/kg and 10 µg/kg for the partial sum of PCB congeners (Table 4-5a).

4.5.2.2 Recent Fish Tissue Data for Lower Saginaw River (Bay County)

Caged fish studies have been conducted in the LSR-BC to evaluate chemical uptake in channel catfish at six locations since 1997. Two locations (upstream of Middle Ground Island and at the river mouth) were sampled in 1998, 2002, and 2005 from which approximately 20 composite whole body fish samples from each location have been analyzed. Four additional sites in the LSR-BC were included in the 2005 caged fish study: the Truman Parkway Bridge, the Seventh Street Bridge, near the Detroit and Mack railroad, and just downstream of Wilder Road. Three to four whole body composite samples were analyzed from each location. As described above, the whole body caged fish samples were analyzed for

PCDD/Fs, total mercury, PCBs (congeners and Aroclors), pesticides and several other compounds (Table 4-1).

PCDD/Fs were consistently detected in the majority of the caged channel catfish samples from the LSR-BC. Concentrations of TEQs were slightly more variable in LSR-BC than in the upstream reach. Concentrations of PCDD/F TEQs in caged channel catfish tissue samples ranged from 1.7 ng/kg to 3.7 ng/kg and averaged 2.8 ng/kg (Table 4-5b). Total mercury concentrations in the caged fish were similar to the upstream reach, ranging from 0.01 mg/kg to 0.03 mg/kg and averaging 0.016 mg/kg. PCB concentrations, however, were higher in the caged channel catfish samples from the LSR-BC than in the upstream samples. Three Aroclor mixtures were detected in the caged fish samples and the partial sum of PCB congeners concentrations ranged from 5.0 µg/kg to 310 µg/kg. The average partial sum of PCB congeners from the LSR-BC (160 µg/kg) was 25 times greater than in the upstream reach (6.5 µg/kg; Tables 4-5a, b). Dioxin-like PCB TEQs in caged channel catfish from the LSR-BC ranged from 62 ng/kg to 180 ng/kg and averaged 100 ng/kg. Detected concentrations of most pesticides were similar in the LSR-BC caged fish samples as in the upstream reach.

In addition to the caged channel catfish samples, MDEQ also collected approximately ten resident (i.e., free swimming) carp from near the Lafayette Street bridge in 2004 for edible tissue (i.e., fillet with skin) analysis. The fillet samples were not analyzed for PCDD/Fs, but were analyzed for total mercury, PCBs, and pesticides (Table 4-1). The detected chemicals from all recent LSR-BC fish samples are summarized in Table 4-5b.

The concentrations of total mercury in resident common carp fillets ranged from 0.03 mg/kg to 0.23 mg/kg and averaged 0.138 mg/kg, while the partial sum of PCB congeners ranged from19 µg/kg to 3,600 µg/kg and averaged 1,070 µg/kg (Table 4-5b). Concentrations of pesticides in the resident carp fillets were similar to the reported concentrations in the caged channel catfish samples.

4.5.2.3 Recent Fish Tissue Data for Saginaw Bay

MDEQ has collected all three types of fish tissue monitoring data from Saginaw Bay since 1997: caged whole body channel catfish chemical uptake data, whole body resident species, and fillets from resident species. The whole body caged channel catfish chemical uptake study was conducted with 14 fish from one location in SB in 2005. The caged fish were analyzed as two composite samples for PCDD/Fs, total mercury, PCBs, and pesticides. Since 1997, MDEQ has also collected 366 resident fish from four species (alewife, common carp, walleye, and spottail shiner) at three locations in SB for whole body tissue analysis. All whole body tissue samples were analyzed for total mercury, PCBs, and pesticides. Resident common carp samples collected in 2005 were also analyzed for PCDD/Fs. Three composites of 50 fish each were analyzed for alewives and spottail shiners. Finally, 89 resident fish from six species have been collected from two locations in SB for fillet tissue analysis since 1997. The skins were included with the fillets for common carp and channel catfish, but not for the other four species (walleye, white bass, white sucker, and yellow perch). The fillet samples were analyzed for total mercury, PCBs, and pesticides, while fillets from channel catfish collected in 1999 were also analyzed for PCDD/Fs. Therefore, recent PCDD/F TEQ data from SB are available from caged channel catfish, whole body common carp samples, and channel catfish fillets. The concentrations of PCDD/F TEQs in caged channel catfish from SB were similar to those from the Saginaw River locations. The results from all recent fish samples from SB are summarized in Table 4-5c.

As mentioned above, the caged channel catfish were analyzed for PCDD/Fs, mercury, PCB congeners, and pesticides. Data for all 17 PCDD/F congeners required to calculate PCDD/F TEQs were not available. As further discussed in Section 4.5.2.4, TEQ concentrations were calculated based on a subset of the 17 PCDd/F congeners that are typically used to calculate TEQ concentrations. There were data for a minimum of 15 of the congeners in all samples and these partial sum TEQs are hereafter referred to as TEQ'. TEQ' concentrations from the two whole body composite, caged catfish samples (2.1 ng/kg and 2.7 ng/kg) fall within the range of TEQs from caged catfish samples from the Saginaw River. The mercury concentrations (0.012 mg/kg and 0.016 mg/kg) from SB and dioxin-like PCB TEQs (80 ng/kg and 87 ng/kg) were comparable to the concentrations observed in the caged fish studies conducted in the Saginaw River, while the partial sum of PCB congeners (140 µg/kg and 150 µg/kg) in the two composites from the bay were generally lower than the caged fish tissue concentrations reported in the stations in the river. However, the concentrations reported in the river include samples from caged fish studies conducted prior to sediment remediation in LSR-BC and may only be partially representative of current conditions. Finally, DDTs, chlordanes, and dieldrin were detected in both composite samples of caged channel catfish from SB at concentrations similar to those reported in the upstream caged fish studies.

The resident wild fish tissue data for SB incorporate many more species than the wild fish tissue data from the river. However, PCDD/Fs were target analytes for just two resident fish species: channel catfish fillets and whole body carp samples. The higher concentrations of PCDD/F TEQs were observed in the resident common carp whole body samples, which ranged from 5.0 ng/kg to 53 ng/kg and averaged 25 ng/kg. Concentrations of PCDD/F TEQs in the SB resident channel catfish fillets ranged from 5.1 ng/kg to 22 ng/kg and averaged 10 ng/kg (Table 4-3a).

Mercury was detected in all wild fish samples collected from SB. The highest total mercury concentrations reported were for walleye, in which whole body mercury concentrations ranged from 0.1 mg/kg to 0.75 mg/kg and averaged 0.36 mg/kg. Walleye fillet concentrations similarly ranged from 0.07 mg/kg to 0.7 mg/kg and averaged 0.31 mg/kg (Table 4-5c). Common carp had the next highest whole body total mercury concentrations, which ranged from 0.03 mg/kg to 0.38 mg/kg and averaged 0.10 mg/kg. Resident alewife and spottail shiner both had total mercury concentrations in whole body samples of less than or equal to 0.02 mg/kg. For fillet concentrations, resident channel catfish, white bass, and common carp had the next highest total mercury fillet concentrations behind walleye, with maximum total mercury concentrations up to 0.56 mg/kg and average concentrations near 0.15 mg/kg for all three species. Yellow perch and white sucker had the lowest total mercury fillet concentrations in SB (Table 4-5c).

PCBs were detected in all species of resident fish collected, and Aroclor 1254 was the only Aroclor mixture specifically identified in fish collected from SB. It comprised 100% of the total PCB Aroclors detected in the common carp, channel catfish, and walleye fillets and in the whole body carp and walleye samples. The highest concentrations of PCBs were reported in both the whole body and fillets of common carp and whole body walleye samples; average concentrations of PCB Aroclors exceeded 2,000 µg/kg in each case. The Aroclor concentrations in the walleye fillets, however, were substantially lower than in the whole body samples (Table 4-5c).

PCB congeners were detected in all species of resident fish collected from SB. For the whole body samples, the partial sum of PCB congeners were highest in the common carp and walleye, in which detected concentrations ranged from 290 µg/kg to 5,520 µg/kg and 280 µg/kg to 2,660 µg/kg, respectively. Spottail shiner had the lowest whole body partial sum of PCB congeners, with an average of 180 µg/kg and a range of 140 µg/kg to 220 µg/kg. The highest partial sum of PCB congeners in fillets occurred in carp (2,340 µg/kg) and white bass (1,540 µg/kg), while maximum partial sum of PCB congeners were less than 1,000 µg/kg in channel catfish, walleye, white sucker, and yellow perch (Table 4-5c). Dioxin-like PCB congeners concentration data were only available for two resident fish species: whole body channel catfish and common carp samples. Dioxin-like PCB TEQs ranged from 80 ng/kg to 87 ng/kg in two whole body catfish samples while the range was slightly lower (15 ng/kg to 41 ng/kg) in six whole body carp samples (Table 4-3a).

Finally, the detection frequencies of different pesticides and their residues were variable in SB. For example, DDT and its metabolites were detected in all resident fish tissue samples from SB. The highest total DDT concentrations were observed in whole body carp and walleye samples, in which maximum reported concentrations were greater than 1,000 µg/kg (Table 4-5c). Total DDT concentrations in resident alewife and spottail shiner were substantially lower, with all reported concentrations less than 100 µg/kg. Total DDT concentrations in fillets tended to be lower than the whole body concentrations. The highest fillet DDT concentrations were reported in the two species where the skin was included: common carp and channel catfish (Table 4-5c). Most other pesticides were detected at concentrations less than 100 µg/kg in both whole body and fillet samples.

4.5.2.4 Analysis of Fish Tissue PCDD/F Concentrations in Saginaw River and Bay

Despite a relatively limited collection of data on concentrations of PCDD/Fs in fish in Saginaw River and Bay, statistical analyses were undertaken with the goal of identifying any discernable trends in concentrations across time, space, species, or other attributes. As noted above, whole body caged channel catfish and resident whole body carp represent the only available fish tissue samples from the Saginaw River and Bay with PCDD/F TEQ data. PCDD/F TEQs could not be calculated for many samples because analytical results were not reported for all 17 congeners that contribute to the TEQ. Therefore, PCDD/F TEQs based on the full suite of 17 congeners were calculated when possible. However, in order to maximize the data available for analysis, the TEQ' was calculated using data for all reported congeners. The minimum number of congeners available was 15. Statistical analyses were conducted on both the full TEQ and the TEQ' values.

Statistical analyses were also conducted based on 2,3,7,8-TCDD and 2,3,7,8-tetrachlorodibenzofuran (TCDF) concentrations. 2,3,7,8-TCDD was selected as a representative congener because it is the most toxic congener (Van den Berg et al. 2006) and, therefore, contributes significantly to the calculated TEQ concentrations. 2,3,7,8-TCDF was selected because it is typically among the most abundant PCDD/F congeners in environmental samples from Saginaw River and Bay and it also is one of the more toxic furan congeners.

The limited quantity of fish tissue results for PCDD/Fs in Saginaw River and Bay precluded a number of analyses that would have been of interest, such as the evaluation of trends in fish tissue concentrations across: a) river miles, b) species, c) preparation method, d) length of fish; e) feeding guilds; f) migratory versus resident species; and g) habitat preferences. Based on the available information, only three basic questions could be explored for this analysis, as follows:

- Do concentrations of PCDD/F TEQs, 2,3,7,8-TCDD, and 2,3,7,8-TCDF in fish tissue samples from the Saginaw River differ significantly from those collected from Saginaw Bay?
- Have concentrations of PCDD/F TEQs, 2,3,7,8-TCDD, and 2,3,7,8- TCDF concentrations in fish tissue from Saginaw River and Bay changed significantly over time? If so, how?
- Is there a significant relationship between concentrations of PCDD/F TEQs 2,3,7,8-TCDD, and 2,3,7,8-TCDF in fish tissue and in sediment from Saginaw River and Bay?

The following discussion describes the spatial and temporal trends that can be discerned from the available data on PCDD/Fs in caged channel catfish and resident carp samples.

Caged Channel Catfish

Spatial trends in PCDD/F TEQ concentrations (river vs. bay) cannot be determined for caged channel catfish due to limited reporting of results for all 17 congeners. Evaluation of spatial trends in the TEQ', 2,3,7,8-TCDD and 2,3,7,8-TCDF concentrations was also hindered by low sample sizes in Saginaw Bay; results are only available for two caged catfish samples from Saginaw Bay. Thus, while average concentrations of TEQ', 2,3,7,8-TCDD, and 2,3,7,8-TCDF in caged channel catfish from the river and bay were found to be similar (approximately 2.5 ng/kg, 0.7 ng/kg, and 2.0 ng/kg, respectively), the limited sample size in the bay prevents any meaningful comparison of caged tissue concentrations between Saginaw River and Bay.

Concentrations of PCDD/F TEQs, 2,3,7,8-TCDD, and 2,3,7,8-TCDF in caged channel catfish are available from sampling events conducted in 1992, 2002, and 2005. There were no significant temporal patterns in average TEQs, 2,3,7,8-TCDD, and 2,3,7,8-TCDF concentrations from 1992 through 2005 (Figure 4-3). Although the average TEQ' concentration appeared to increase from 1992 through 2005 (Figure 4-3), the small sample size from 1992 (n=3) does not support a reliable analysis of temporal trends in TEQ'. Therefore, the recent whole body caged channel catfish data provide no evidence that PCDD/F uptake has changed since 1992 in Saginaw River and Bay. In addition, they do not provide sufficient data for a more detailed analysis.

Finally, the whole body PCDD/F concentrations in caged channel catfish were compared with the average sediment PCDD/F concentrations over the nearest kilometer of the river in order to determine if there was a simple relationship between sediment and whole body, caged catfish concentrations. It was not possible to use average sediment concentrations over smaller areas because sediment samples were not collected within less than a kilometer from all caged catfish deployment locations. Therefore, although a significant relationship was reported between caged channel catfish samples and sediment PCB concentrations from the Saginaw River in 1993 (Echols et al. 2000), there was no significant relationship between the fish and sediment concentrations of PCDD/F TEQ, TEQ', 2,3,7,8-TCDD, and 2,3,7,8-TCDF even after accounting for fish lipid content, sizes of fish, and sediment organic carbon content. However, the earlier work included sediment samples that were co-located and collected concurrent with the caged catfish deployments. For the PCDD/F analysis described here, sediment samples were not collected in conjunction with caged fish deployments and were therefore collected from different locations and on different dates. In addition, any potential relationship between fish and sediment concentrations of PCDD/Fs would likely be influenced by complex factors such as the river stage during cage deployment, erosional/depositional characteristics of the nearby river bottom, and suspended sediment load.

Resident Carp

PCDD/F concentrations were not available for any whole body, resident carp samples collected from the Saginaw River. Therefore, it is not possible to evaluate spatial trends in resident carp fish tissue concentrations from the river and bay. The following analysis focuses solely on samples collected from Saginaw Bay.

PCDD/Fs (including 2,3,7,8-TCDD and 2,3,7,8-TCDF) were measured in whole body, resident carp samples collected from Saginaw Bay during five sampling events between 1992 and 2005. All resident carp samples were collected from the same location in Saginaw Bay, approximately one mile northwest of the mouth of the Saginaw River.[44] PCDD/F TEQ concentrations were only available for samples collected in 1998 and 2001. Although the average PCDD/F TEQ concentrations were similar both years (approximately 2.5 ng/kg), it is not possible to quantitatively evaluate temporal trends with only two sample dates. TEQ', 2,3,7,8-TCDD, and 2,3,7,8-TCDF concentrations were available for all five sampling events, however. 2,3,7,8-TCDD concentrations show a slight but statistically significant (R^2= 0.2; $p<0.01$) decline from 1992 through 2005 (Figure 4-4). Accounting for the lipid content and size of fish in individual samples does not improve the strength of the relationship. TEQ' concentrations show a similar but marginally significant ($p=0.04$) decline over the same time period. The weaker relationship with TEQ' likely indicates that 2,3,7,8-TCDD is a major component of the TEQ' in resident channel catfish. Finally, there was no significant relationship between year and 2,3,7,8-TCDF concentrations in resident carp demonstrating that individual PCDD/F congeners may exhibit distinct patterns in the environment.

Finally, as mentioned above, the resident carp collected from Saginaw Bay were all collected from the same location. Therefore, it was not possible to

[44] Site number 699: http://www.deq.state.mi.us/fcmp/Sites.asp

evaluate any relationship between resident fish tissue concentrations and sediment concentrations in Saginaw Bay.

4.5.3 Chemicals in Mammals

Although many toxicological tests have been conducted on farm-raised mink fed fish caught from the Saginaw River (e.g., Tillitt et al. 1996, Bursian et al. 2006), no studies were identified that evaluated chemical exposures among wild mammals inhabiting Saginaw River and Saginaw Bay.

4.5.4 Chemicals in Birds

Bird deformities were reported throughout the Great Lakes region from the 1960s through the early 1990s. Indeed, several studies included data collected from Saginaw Bay in the 1980s (Fox et al. 1991, Giesy et al. 1994). In addition, several studies reported widespread decreases in reproduction and increases in developmental abnormalities in birds from the Saginaw Bay ecosystem shortly after the 1986 flood event (Ludwig et al. 1993, Ludwig et al. 1995). However, there are few more recent data on the status of birds from the study area. This section summarizes the most recent data available concerning tissue concentrations in birds from the Saginaw River and Bay.

Since 1999, MDEQ has monitored chemical concentrations in nestling bald eagles and herring gull eggs. The bald eagle monitoring began in 1999 and includes analysis of nestling breast feathers for mercury and nestling blood samples for 20 PCB congeners, DDT and its metabolites, chlordane, dieldrin, and other organochlorine compounds. The bald eagle sampling schedule covers nests within 20% of designated watersheds annually, such that all designated watersheds are monitored on a rotating basis.

The data summaries in Table 4-6 reflect data from 1999 through 2002 (Summer et al. 2002, Roe et al. 2003, 2004a, 2004b), focusing on nesting sites near or on Saginaw Bay or the lower Saginaw River. Total DDT concentration ranged from 2.738 μg/kg (ww) at Rifle River Recreation area to 48.77 μg/kg (ww) at Big Charity Island, which is located off Point Lookout in outer Saginaw Bay. Total PCB concentrations ranged from 4.41 mg/kg to 182.95 mg/kg. The concentrations of PCBs sampled from birds at Big Charity Island were the highest sampled in the area. Due to analytical difficulties, results for mercury concentrations were not available (Roe et al. 2004b).

Sample collection and analysis of herring gull eggs began in 2002. Samples are analyzed for mercury, PCBs, and chlorinated pesticides (e.g., DDT/DDE/DDD). Although herring gull eggs are sampled from Little Charity Island in Saginaw Bay, analytical results are not publicly available.

Given the paucity of data on chemical concentration in birds, Froese et al.'s (1998) study of tree swallow exposure, discussed above, is also worth considering. As previously noted, Froese et al. (1998) measured concentrations of PCBs in eggs and nestlings of tree swallows collected in 1992 from three sites in the lower Saginaw River. The mean concentration of total PCBs in eight egg samples was 15 mg/kg (lipid), while the mean concentration of total PCBs in 14 nestling samples was 16 mg/kg (lipid). Froese et al. (1998) concluded the concentrations of dioxin-like PCBs in Saginaw River were below the threshold for adverse effects in tree swallows.

5. STATUS AND TRENDS

The foregoing summary presents a range of data reflecting current understanding of environmental conditions of the Saginaw River, its floodplain, and Saginaw Bay, spanning physical, biological, chemical, and anthropogenic attributes.

The findings of this CCR are generally consistent with findings by the governments of Canada and the U.S., as described in the recently issued draft State of the Great Lakes 2007[45] (USEPA and Environment Canada 2007). Several of the trends in environmental conditions that are prevalent throughout the Great Lakes are listed in Text Box 5-1, as excerpted from that report. In addition, the State of the Great Lakes 2007 calls out several observations specific to Saginaw Bay as outlined in Text Box 5-2.

The State of the Great Lakes 2007 (USEPA and Environment Canada 2007) recognizes that many of the remaining environmental issues within the Great Lakes occur at the AOCs established under the GLWQA. Under the Great Lake Water Quality framework, the condition of AOCs is classified with respect to impairment of 14 types of beneficial uses. Beneficial use impairments are generally classified into three categories: 1) restrictions on the consumption of fish, wildlife, and drinking water; 2) impacts to ecological communities; and 3) impacts on human use. As previously discussed, the Saginaw River/Bay AOC is currently classified as impaired for 12 out of 14 beneficial uses. Nutrient enrichment contributes to two-thirds of the impairments while toxic contaminants, such as PCBs and PCDD/Fs, contribute to a quarter of them (Saginaw Bay NWI 1994).

The Saginaw River/Bay AOC was among the first AOCs in the region to initiate the RAP process, and restoration actions have been initiated for the Saginaw River/Bay AOC. The original RAP completed in 1988 included 101 recommended actions for restoring the beneficial uses of the river and bay, such as source control, runoff control, targeted dredging, and the creation or protection of habitat (Saginaw Bay NWI 1994). As of 1994, two thirds of the restoration actions had been at least partially implemented, including the 37 highest priority actions (Saginaw Bay NWI 1994). For example, Saginaw Basin Watershed Council was established to promote cooperation between local governments on river management issues,

[45] http://www.epa.gov/glnpo/solec/sogl2007/sogl2007_070601.pdf

Text Box 5.1

Environmental Trends Throughout the Great Lakes as Excerpted from the State of the Great Lakes (USEPA and Environment Canada 2007)

- Concentrations of most chemicals or chemical groups have declined significantly over the past 30 years. There is a marked reduction in the levels of toxic chemicals in air, water, biota, and sediments.
  - Herring gulls: Concentrations of contaminants such as PCBs and pesticides (e.g., DDTs) in herring gull eggs vary from good in Lake Superior, to mixed in Lake Michigan, Lake Erie, and Lake Huron, to poor in Lake Ontario. Despite the decline in frequency of gross effects in wildlife, many subtle effects of contamination that were not measured in earlier years remain in herring gulls.
  - Juvenile spottail shiner: Concentrations of DDT and PCBs have declined in this indicator of nearshore contamination over the last 30 years. DDT concentrations still exceed the GLWQA criterion at most locations, but PCB concentrations are below the GLWQA criterion at many, but not all, sites in the Great Lakes.
- Despite improvements in concentrations of contaminants in the Great Lakes, many biological components of the ecosystem are severely stressed:
  - Populations of native species near the base of the foodweb (such as zooplankton) are in decline in some of the Great Lakes.
  - Native preyfish populations have declined in all lakes except Lake Superior.
  - Walleye harvests have improved but are still below fishery target levels.
  - Lake sturgeon are locally extinct in many tributaries and waters where they once spawned and flourished.
  - Habitat loss and deterioration remain the predominant threat to Great Lakes amphibian and wetland-dependent bird populations.
- Phosphorus loadings to the Great Lakes have been reduced over the past 30 years, but high phosphorus concentrations are still measured in some embayments, harbors, and nearshore areas. In addition, nuisance growth of green algae has reappeared along the shoreline in many places, likely reflecting the increased availability of phosphorus.
- The introduction of aquatic species, primarily in ship ballast water, has increased exponentially since the 1830s. It is one of the greatest threats to the biodiversity and natural resources of the Great Lakes, second only to habitat destruction.

Text Box 5.2

Saginaw Bay Observations Excerpted from the State of the Great Lakes (USEPA and Environment Canada 2007)

- The walleye fishery in Lake Huron is at historical levels, but remains far below targets. Recent improvements in reproductive success of walleye in Saginaw Bay between 2003 and 2005 are attributed to the 99% decline in alewife numbers. The yellow perch population in Saginaw Bay has similarly benefited from the reduction in alewifes.
- Although most sites in Lake Huron are now categorized as oligotrophic based on aquatic oligochaete community metrics, Saginaw Bay has remained mesotrophic for the last six years.
- While herring gull eggs from two of the three monitoring sites in Lake Huron had the lowest PCB concentrations measured among the 15 monitoring sites throughout the Great Lakes in 2005, eggs from the monitoring site in Saginaw Bay had the highest PCB concentration of all sites.
- Both PCBs and DDT in whole fish show general declines in concentrations in Lake Huron. However, PCB and DDT loading to Saginaw Bay continue to be reflected in fish tissue.
- The mayfly (*Hexagenia*) population is monitored as an indicator of ecosystem health because it is a preferred food for many freshwater carnivores. The status of the *Hexagenia* population is poor in Lake Huron, but the trend over time cannot be determined due to a lack of historical data. However, *Hexagenia* are believed to have been abundant in Saginaw Bay until early 20th century. Their current absence from Saginaw Bay was confirmed in 2001.
- Abundant stocks of lake sturgeon of mixed sizes are consistently caught in Saginaw Bay, although populations continue to be well below historical levels. Spawning occurs in the Rifle River in Saginaw Bay.
- Coastal wetland community health, as determined by invertebrate and plant community assessments, in Saginaw Bay scored low relative to other sites in Lake Huron. Wetland plant communities in Saginaw Bay have been impacted by: plowing, raking, and mowing during low water; explosive expansion of reed (*Phragmites australis*); and high turbidity water from agricultural runoff impeding the growth of submerged aquatic plants.

storm water runoff management plans were being developed, the Saginaw Bay National Watershed Initiative funded numerous erosion control activities throughout the watershed, numerous restoration wetland restoration projects have been funded throughout the watershed, and cleanup or corrective actions were conducted at a variety of hazardous waste sites including the Consumers Power Company Karn-Weadock Power Plant, Union Oil Terminal, Dow Terminal, General Motors Powertrain facility, and many others (Saginaw Bay NWI 1994). Although none of the beneficial use impairments have been officially removed, improvements have been reported in many of the types of impairments including the number and extent of beach closings, restrictions in dredging due to contaminated sediments, reported incidences of tainting of fish flavor from the river or bay, and dissolved oxygen concentrations in the river and bay (PSC 2002).

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