ST. MARYS RIVER

PHYSICAL AND HYDRAULIC CHARACTERISTICS[1]

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1. INTRODUCTION

The St. Marys River forms the outlet of Lake Superior, connecting Whitefish Bay with Lake Huron through De Tour Passage. Lake Superior and the St. Marys River are both highly regulated. The Soo Locks bypass the St. Marys River Rapids and make navigation possible between Lakes Superior and Huron.

2. PHYSICAL CHARACTERISTICS

From its nominal head at Point Iroquois, the river flows in a general southeasterly direction through several channels covering a distance of from 101 km to 121 km (63 mi to 75 mi), depending on the route taken, with a total fall of about 6.7 m (22 ft). Approximately 6.1 m (20 ft) of this fall occur in the St. Marys Rapids, which are less than 1.5 km (1 mi) long and form a very short middle reach with distinct hydraulic characteristics. Altogether, there are three different hydraulic reaches in the St. Marys River.

2.1 The Upper Reach

The upper river reach, which is above the rapids (figure 1), spans 23 km (14 mi) and falls less than 0.1 m (0.2 ft) under a very mild slope. It forms a single channel, with the navigation channel running along the midchannel deeper water. The initial segment of this reach is very wide, approaching 6.4 km (4 mi), and runs for about 10 km (6 mi) in a southeasterly direction from the nominal river head beginning at the Point Iroquois-Gross Cap cross section. However, nearly one-half of this width is generally very shallow and hydraulically ineffective. The midchannel depths are generally 12-18 m (40-60 ft), but vary from 9 m (30 ft) around dredged shoals to a maximum of about 30 m (100 ft). Downstream, the river turns easterly for about 5 km (3 mi) and narrows to a total width of about 2.5 km (1.5 mi) at Cedar Point, then swings to the northeast at a sharp constriction of 760 m (2,500 ft) opposite Brush Point-Point aux Pins and runs for about 8 km (5 mi) to the Soo Locks and the St. Marys Falls. Effective channel width in this segment of the upper river varies from 300 m to 900 m (1,000 ft to 3,000 ft), with most of the river width occupied by very shallow [a meter (a few feet) deep] embayments along the shores. Channel depths vary from about 8.5 m (28 ft) secured by dredging around shoals and shallows to a maximum approaching 15 m (50 ft).

2.2 The Rapids Reach

The St. Marys Rapids reach has a total river width of about 1,500 m (5,000 ft), but nearly half of this width is occupied by islands and land fills around locks. The Soo Locks, the regulating works, and the power canals

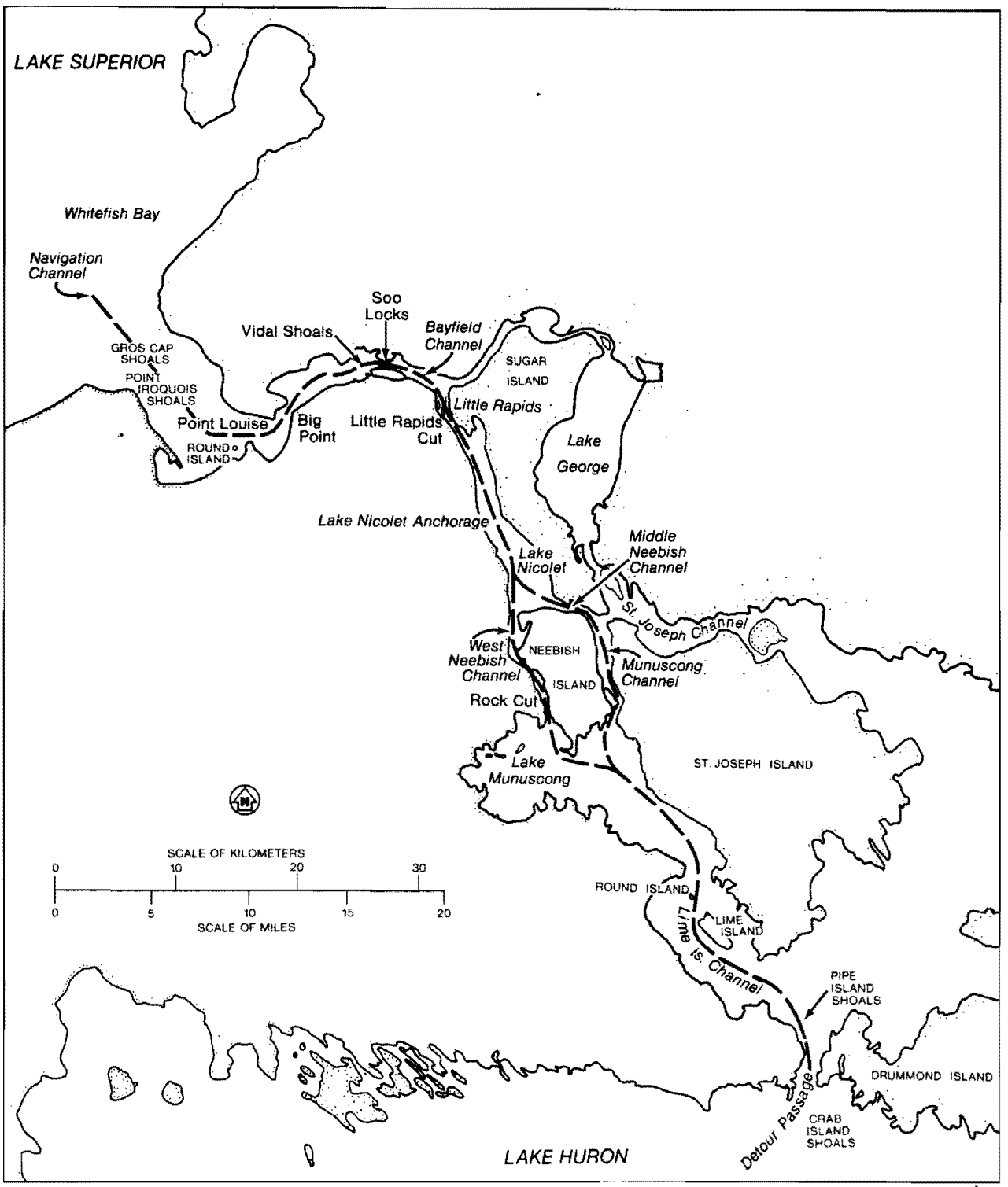

FIGURE 1.--*St. Marys River channel.*

are shown in figure 2. Outside of locks and connecting navigation channels, the natural river depths in this reach are very shallow, generally under 1.5 m (5 ft). The St. Marys Rapids, in the middle of the reach, are about 400-m (1,300-ft) wide and 1,200-m (4,000-ft) long.

The Soo Locks located between the cities of Sault Ste. Marie (Mich. and Ont.) are operated during the navigation season, which usually extends for about 9 months each year from April through December. The lock system consists of four parallel United States locks, which can be used by deep-draft vessels, and an older and smaller Canadian lock used primarily by small ships and pleasure craft to relieve congestion at the American locks. The locks and their dimensions are listed below in a south to north order:

Lock	Length (m)	Length (ft)	Width (m)	Width (ft)	Depth (m)	Depth (ft)
Mac Arthur	244	(800)	24	(80)	9.4	(31.0)
Poe	366	(1,200)	34	(110)	9.8	(32.0)
Davis	411	(1,350)	24	(80)	7.0	(23.1)
Sabin	411	(1,350)	24	(80)	7.0	(23.1)
Canadian	274	(900)	18	(59)	5.1	(16.8)

The Mac Arthur Lock handles primarily downbound, loaded ships with an overall length and beam up to 220 m and 23 m (730 ft and 75 ft), respectively. The Poe Lock handles vessels that the Mac Arthur Lock cannot service, mostly the "1,000 footers"; it can handle ships as long as 335 m (1,100 ft) and as wide as 32-m (105-ft). The Davis and Sabin Locks are identical in size and handle most of the upbound, ballasted ships having length and beam dimensions up to 252 m and 23 m (826 ft and 75 ft), respectively, but their use is generally depth-limited.

2.3 The Lower Reach

The lower reach is that part of the river between the rapids and Lake Huron. It comprises 77-97 km (48-60 mi) of multiple channels. The fall [about 0.6 m (2 ft)] of the generally wide lower river occurs in several narrow channels interrupted by wide pools or lakes. The lower river is characterized by generally broad and shallow multiple river channels containing dredged navigation channels, except for a short, single channel at the head of the reach and the lower end. The Bayfield Channel, which is between the lower lock canals and Sugar Island, is about 3 km (2 mi) long, with total river width increasing from 600 m (2,000 ft) to about 1,500 m (5,000 ft). A dredged navigation channel about 600-m (2,000-ft) wide runs for most of this length, with maximum depths of 8.5 m (28 ft). At the downstream end, the

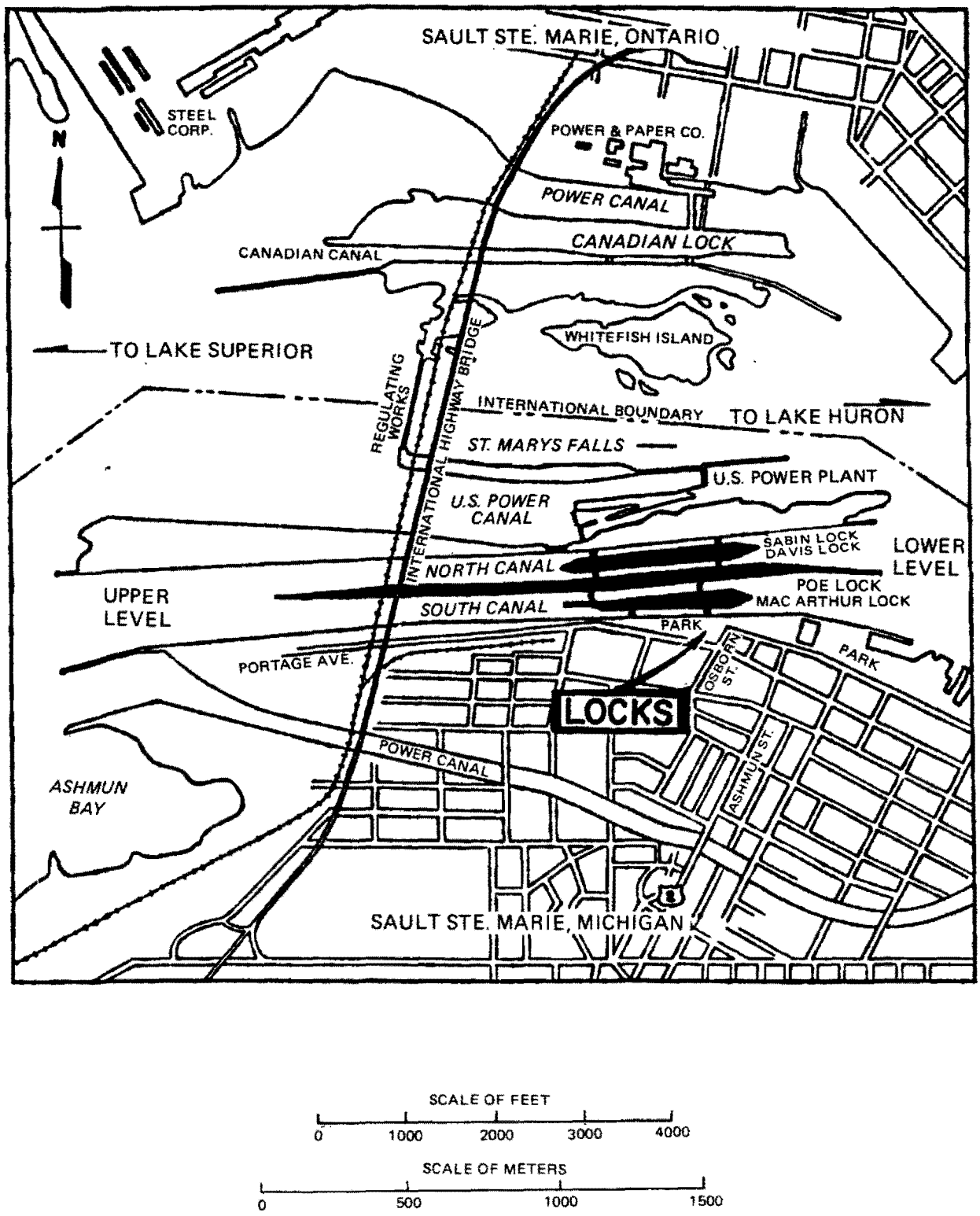

FIGURE 2.--*St. Marys Falls and the Soo Locks.*

dredged channel narrows to 400 m (1,300 ft) and the undredged part of the river is shallow. At the head of Sugar Island, the river channel divides. The main navigation channel runs for about 74 km (46 mi) in a general southeasterly direction along the Michigan mainland, passing west of Sugar Island, around Neebish Island, west of St. Joseph Island, and west of Drummond Island through De Tour Passage to Lake Huron (fig. 1). A secondary navigation route, for small craft, runs between the Ontario mainland and Sugar Island, first in an easterly, then in a southerly direction, north and east of the island, respectively. At the downstream end of Sugar Island, this channel divides again, passing west between Sugar and St. Joseph Islands to rejoin the St. Marys River or east through the St. Joseph Channel to North Channel and Georgian Bay.

The main river channel west of Sugar Island passes through the Little Rapids and Lake Nicolet to the head of Neebish Island. The Little Rapids segment is about 3-km (2-mi) long, decreasing in the overall width downstream from about 1,200 m to 450 m (4,000 ft to 1,500 ft). Most of this river segment is occupied by small islands and very shallow water, and is bisected with a dredged navigation channel 180-m (600-ft) wide and 8.2-m (27-ft) deep. This navigation channel extends for approximately 3 more km (2 mi) through the Upper Lake Nicolet, where it gradually widens to 450 m (1,500 ft) with separate upbound and downbound routes. The 450-m (1,500-ft) channel is 8.8-m (29-ft) deep and extends downstream through the Middle Lake Nicolet for about 6 km (4 mi). At the lower end of this channel, a flared (both ends) 300-m (1,000-ft) wide and 8.5-m (28-ft) deep anchorage area is attached on the west side of the channel, for a total width of 750 m (2,500 ft) running for 1.5 km (1 mi) at the midpoint. The total width of the Upper and Middle Lake Nicolet is about 1.5 km (1 mi), but the natural depths outside the navigation channel seldom exceed 3 m (10 ft). In the next 3 km (2 mi), the width of Lake Nicolet approximately doubles and extends for an additional 3 km (2 mi) above Neebish Island. In this area of the lake, the navigation routes proceed along separate extensions of the West Neebish Channel for downbound and the Middle Neebish Channel for upbound traffic.

The West Neebish Channel passes west of Neebish Island and has a total length of about 27 km (17 mi) between the junctions with the Middle Neebish Channel in Lake Nicolet at the upper end, and Lake Munuscong at the lower end. Except for widenings at the turning basins, the navigation channel is 90-m (300-ft) wide and 8.2- to 8.5-m (27- to 28-ft) deep. Most of the channel required dredging, except for the area around the lower junction in Lake Munuscong, where natural depths approach 9 m to 15 m (30 ft to 50 ft). The shallow river channel between the island and the Michigan mainland consists of two embayments--approximately 4-km (2.5-mi) long and 0.8-km (0.5-mi) wide--and a centrally located deep narrows--about 2.5 km (1.5-mi) long and only 90- to 150-m (300- to 500-ft) wide. The Middle Neebish Channel passes north and east of the island and is also about 27-km (17-mi) long between the upper and lower channel junctions. This channel consists of two adjacent navigation channels with a total width of 150 m (500 ft), except for wider turning basins. The westerly side of the channel is 90-m (300-ft) wide and 8.2- to 8.5-m (27- to 28 -ft) deep, and the easterly side 60-m (200-ft) wide and 6.4-m (21-ft) deep. The total width of this river channel between the lakes varies from approximately 0.8 km to 1.5 km (0.5 mi to 1 mi) and is mostly shallow, usually

less than 6.0-m (20-ft) deep outside of the dredged navigation channel. The Middle Neebish Channel proper, between Neebish and Sugar Islands, is about 5-km (3-mi) long and 0.8-km (0.5-mi) wide; the channel between Neebish and St. Joseph Islands, also called Munuscong Channel, is about 11-km (7-mi) long, with approximately equal upper and lower channel segments about 1.5-km and 0.8-km (1-mi and 0.5-mi) wide, respectively. The last segment of this channel to about the middle of Lake Munuscong runs along a trough with natural depths of about 9 m (30 ft). Lake Munuscong forms a large embayment measuring about 14 km by 8 km (9 mi by 5 mi), and is generally very shallow, with depths in most areas under 1.8 m (6 ft).

The last major portion of the main lower river channel passes through generally wide and deep water between the Neebish Channels and Lake Huron, with dredging limited to shoals along the navigation routes. The channel passes for about 10 km (6 mi) in a southeast direction through the elongated eastern section of Lake Munuscong, with a midchannel trough about 1.5-km to 2.5-km (1-mi to 1.5-mi) wide and 9-m to 12-m (30-ft to 40-ft) deep. Below the lake, the channel turns south and runs for about 6 km (4 mi) to the Lime Island Channel, south of the island. The navigation channel between Round and Lime Islands was dredged to 8.5 m (28 ft) through extensive shoaling. The Lime Island Channel runs in a southeast direction for about 13 km (8 mi) to De Tour Passage, where the river channel turns south again for the last 5 km (3 mi) through the 1.5-km (1-mi) wide passage. The total river width generally varies from 3 km to 6 km (2 mi to 4 mi), with deep channels occupying approximately half the width. Midchannel depths in the Lime Channel vary from 9 m to 27 m (30 ft to 90 ft), and the entire De Tour Passage is very deep, with maximum depths of 30-40 m (100-130 ft).

The second lower river channel, through Lake George, is 20 km (12 mi) longer and provides an alternate navigation route for small vessels and pleasure craft, with a width of about 45 m (150 ft) and depth of 3.7 m (12 ft), for a total distance of about 43 km (27 mi). The channel begins at the intersection of Bayfield and Little Rapids Channels, and passes through the Old North Channel in a northeasterly direction to Little Lake George, then easterly to Lake George, a total distance of about 19 km (12 mi). Outside the midchannel navigation route with depths of 4.0 m (13 ft) to about 12.2 m (40 ft), this channel is very shallow and varies in width from approximately 300 m to 600 m (1,000 ft to 2,000 ft), widening at Little Lake George to about 2.5 km (1.5 mi). At the head of Lake George, the river turns south and passes through the lake, which is about 16 km (10 mi) long. Upper Lake George is about 5-km (3-mi) wide and generally deep, with maximum depths between 9 m and 15 m (30 ft and 50 ft). The lower portion of the lake widens to about 6 km (4 mi), but is generally very shallow, mostly 0.3 m to 0.9 m (1 ft to 3 ft). From Lake George, the river channel is about 600-m (2,000-ft) wide and proceeds in a southerly direction for about 6 km (4 mi), passing west of East Neebish Island, with midchannel depths between about 6 m and 15 m (20 ft and 50 ft). Above St. Joseph Island, the channel divides; one branch turns west, passing through a short connection between Sugar and St. Joseph Islands to join the Middle Neebish Channel. This channel is about 1.5-km (1-mi) long and 0.8-km (0.5-mi) wide, with a maximum depth of 4.0 m (13 ft). The other branch turns east to join the St. Joseph Channel, which forms another navigation channel with a minimum depth of about 3.7 m (12 ft). This branch leads into North Channel and eventually Georgian Bay.

3. HYDRAULIC CHARACTERISTICS

3.1 River Discharge

Flow in the St. Marys River produces an average discharge of about 2,100 $m^3 s^{-1}$ (75,000 $ft^3 s^{-1}$), which varies seasonally from a winter low of about 1,800 $m^3 s^{-1}$ (65,000 $ft^3 s^{-1}$) to a summer high of about 2,400 $m^3 s^{-1}$ (85,000 $ft^3 s^{-1}$) per month. The river flow is regulated and the short-period flows can be highly variable due to peaking and ponding operations by power plants. Periodic long-term low and high mean annual flows produced by below-normal and above-normal water supplies vary from about 1,400 $m^3 s^{-1}$ to 3,100 $m^3 s^{-1}$ (50,000 $ft^3 s^{-1}$ to 110,000 $ft^3 s^{-1}$), respectively. The range of seasonal variation in monthly flows is within 140 to 1,300 $m^3 s^{-1}$ (5,000 to 45,000 $ft^3 s^{-1}$).

River discharge and velocity records are available from the U.S. Army Corps of Engineers (COE) in Detroit, Mich., who are responsible for flow measurements and data in the Great Lakes connecting channels. The COE also has a one-dimensional mathematical transient model for the St. Marys River (no published documentation), which can be used to compute river flows, but is not routinely operational. The river flows are controlled by the Lake Superior Regulation Plan, operated by the COE, which normally calls for monthly changes in gate settings at the compensating works (if needed) during the navigation season (April-December) and no changes during winter. The COE also controls lock operations, but has no control over the peaking and ponding operations by powerplants, which are responsible for most of the high, short period (hourly or daily) variations in flow. Because of complicated controls difficult to determine on a daily basis, the St. Marys River flows are normally provided by the COE for monthly periods. However, daily flows can be obtained on request; these could consist of computed model flows or flows compiled from lockage, control, and power structure records.

3.2 Flow Distribution

Flow distribution in the lower St. Marys River is rather complex, with the amount and proportion of flow in different channels dependent to some extent on gate openings in the control structure (lock and power operations also affect river flows). In the upper end of this river reach, flow division between the Little Rapids and Old North Channels is usually about 71 percent and 29 percent, respectively. Flow distribution between the West and Middle Neebish Channels generally amounts to about 26 percent and 45 percent of total flow, respectively. Flow in the short connecting channel between Sugar and St. Joseph Islands is extremely variable; it can flow in either direction with as much as 10-15 percent of total river flow or it can remain basically static. This flow condition has considerable effect on the proportion of total river flow passing through the St. Joseph Channel (15-45 percent) or on the proportion of the main river channel passing through the Munuscong Channel (30-60 percent) and Lake Munuscong (55-85 percent).

3.3 River Velocities

The variable flow conditions in the St. Marys River are reflected in river velocities, which are also highly variable. Water velocities up to 39 km h^{-1} or 11 m s^{-1} (24 mi h^{-1} or 35 ft s^{-1}) have been measured in the rapids, but the highly variable river currents may change drastically and at times the current over the rapids is slight. The strength of the current depends largely upon the river discharge, which is under control and varied according to water level requirements. The outflow of Lake Superior is regulated and the river discharge controlled by locks, compensating works, and powerhouses. In the navigation channels there may be strong currents below the rapids, depending on flow conditions. Strong currents are normally encountered at the outlets of both the Michigan and Ontario power canals. Surface currents at these power canal locations are normally between 0.9 m s^{-1} and 1.2 m s^{-1} (3 ft s^{-1} and 4 ft s^{-1}), with probable lows around 0.6 m s^{-1} (2 ft s^{-1}) and probable highs approaching 1.5 m s^{-1} (5 ft s^{-1}). Maximum surface currents usually occur in mid channel and are approximately 1.3 times higher than the average velocity in the river cross-section. During storm surges on Lake Superior, the normal flow velocities can be considerably higher (about 1.5 times normal), but storm surges on Lake Huron may reduce normal river velocities by reducing river fall. The east and south winds contribute to high water levels below the locks and low water levels above the locks, and the west and north winds have the opposite effect. The highest river currents in the navigation channel occur at the West Neebish Rock Cut, with high, mean, and low velocities of approximately 1.5 m s^{-1}, 0.9 m s^{-1}, and 0.6 m s^{-1} (5 ft s^{-1}, 3 ft s^{-1}, and 2 ft s^{-1}), respectively. Other locations of high currents in the lower river are the Middle Neebish Channel and the Little Rapids Cut, where the velocities are nearly 0.2 m s^{-1} (0.5 ft s^{-1}) lower.

4. ICE EFFECTS

Ice conditions in the St. Marys River are more severe than in the St. Clair or Detroit Rivers, below Lake Huron, and generally limit the duration of the navigation season. Seasonal icing problems involve pack ice, fast ice, and slush ice. Pack ice consists of broken pieces of ice that have been consolidated and jammed together by winds and currents. Whitefish Bay and the upper St. Marys River are particularly susceptible to formation of pack ice from ice sheets driven from Lake Superior by winter storms. The accumulation of pack ice along narrow passages may extend as much as 9 m (30 ft) below the water surface and reach a height of 4.5 m (15 ft) or more above. Ice formation along shallow channel banks produces fast ice attached to shore. When ice accumulation along the channel is broken by a passing vessel, it initially submerges and then emerges in the wake of the ship as rubble. With low winter temperatures, the rubble quickly refreezes, producing a deeper layer of ice than before. As a result, the ice may be 0.3-m to 0.6-m (1-ft to 2-ft) thick along the shore and 0.6-m to 0.9-m (2-ft to 3-ft) thick in the channel. In some cases, slush ice can accumulate to considerable depth, exceeding 2.5 m (8 ft). During spring breakup of the Lake Superior ice cover, the wind driven slush accumulating in the St. Marys River may extend from the surface to the bottom for short periods of time (a few days).

5. SUMMARY

The St. Marys River connects Lakes Superior and Huron, with a total length of about 101-121 km (63-75 mi), depending on the route taken, and a total fall of about 6.7 m (22 ft). Approximately 6.1 m (20 ft) of this fall occur in the St. Marys Rapids. The river drains the Lake Superior Basin, producing an average discharge of about 2,100 $m^3 s^{-1}$ (75,000 $ft^3 s^{-1}$). Average flow velocities in the St. Marys River vary from about 0.6 m s^{-1} to 1.5 m s^{-1} (2 ft s^{-1} to 5 ft s^{-1}), depending on location and controlling flow conditions. The river flows are controlled by the Lake Superior Regulation Plan. Winter flows are generaly affected by ice.