

also contains Lake St. Clair. Table 1 shows the length, breadth and shoreline dimensions.

Measured along the Great Lakes sailing courses, the distance from the western end of Lake Superior to the Atlantic Ocean is approximately 1700 miles, which includes the 600-mile long St. Lawrence River (Figure 1).

Lake and Land Areas

A remarkable feature of the GLB is that water covers about one-third of the total basin area.

The water surface area ranges from 23 percent of the total basin area for Lake Ontario to 39 percent for Lake Superior. Table 2 shows the percentage covered by water for each basin. Lakes Superior, Michigan, Huron, Erie, Ontario, and St. Clair have a total water surface area of 95,000 square miles, including 235 square miles of International Reach of the St. Lawrence River water surface, terminating at the International Powerhouse near Cornwall, Ontario - Massena, New York. The total land and water area of the Great Lakes Basin is

approximately 296,000 square miles.

Table 2. Percent of Lake Basins Covered by Water

Lake Basin	Percent
Superior	39
Michigan	33
Huron	31
Erie, including Lake St. Clair	26
Ontario	23
All Lakes	32

Table 1 General Great Lakes Physiography Information (Dimensions in Miles)

Description	Lake Superior	Lake Michigan	Lake Huron	Lake St. Clair	Lake Erie	Lake Ontario	Total
Length	350	307	206	26	241	193	
Breadth	160	118	183	24	57	53	
Shoreline including Islands	2,980	1,660	3,180	169	856	726	9,571

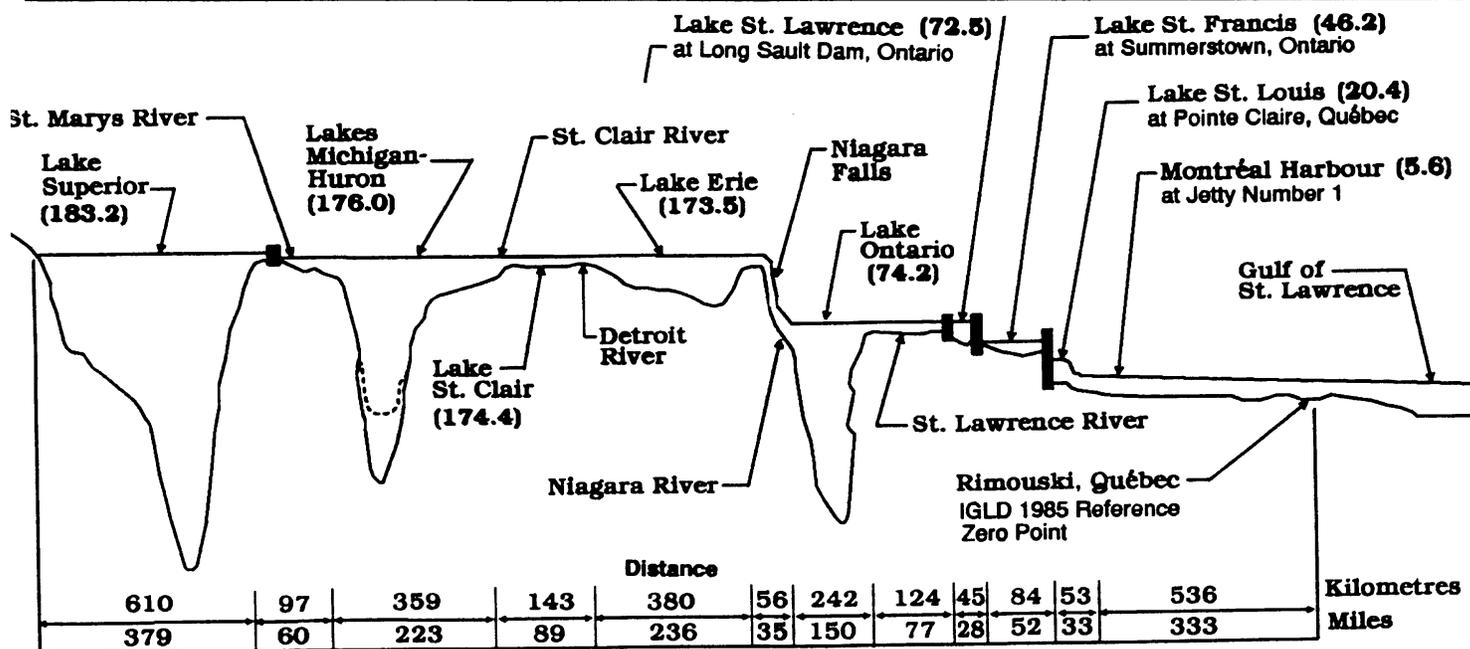


Figure 2. Profile of the Great Lakes - St. Lawrence River

Lake Volumes

When the Great Lakes levels vary from their lowest to highest, the water volume increases only 1.8 percent, from 5,410 cubic miles to 5,510 cubic miles. With the lake levels at low water datum, the total volume of the water in all of the Lakes is approximately 5,440 cubic miles. Lake Superior contains 53 percent of the water; Lake Michigan, 22 percent; Lake Huron, 16 percent; Lake Erie, 2 percent; and Lake Ontario, 7 percent.

The volume of Lake Erie varies from nearly 114 cubic miles to 126 cubic miles during the transition from record low water level to record high water level. The mean depth of the Lake changes from 60.7 feet to 67.1 feet. However, the water surface area increases only 10 square miles during the transition from low water level to high water level. The increase in water surface area is greatest in the west basin where the depth is shallowest.

Measured from low water datum, the greatest known and average natural depths, respectively, of the Great Lakes and Lake St. Clair are: Lake Superior, 1,333 feet and 489 feet; Lake Michigan, 923 feet and 279 feet; Lake Huron, 750 feet and 195 feet; Lake St. Clair, 21 feet and 10 feet; Lake Erie, 210 feet and 62 feet; and Lake Ontario, 802 feet and 283 feet.

Geology

The following is a description of the geology of the lakes.

Lake Superior

Lake Superior is the greatest of the Great Lakes. It is higher, larger, and deeper than the other Great Lakes. At its maximum depth of 1,333 feet, the lake extends 733 feet below sea level. The distance from its shore to the perimeter of its drainage basin generally varies from 2 to 75 miles, except near Lake Nipigon where the distance is 150 miles.

An escarpment near the lakeshore rises 400 to 800 feet above the lake surface on all sides, except the southeast. This escarpment and the western lake bottom consist of very hard, metamorphosed Precambrian age rock formations that formed the highlands bordering a large trough or synclinal basin. Several hundred million years of erosion have worn down the rugged highlands until they are part of the undulating plain. Rock formations southeast of Lake Superior are of the early Paleozoic age. The southeastern lakeshore and lake bottom are largely underlain by sandstone and limestone.

The continental glaciers that swept across Canada and the northern United States during the ice ages rounded and smoothed the ridges of hard rock and gouged out the softer rocks and sediments within the preglacial Lake Superior basin. As they retreated, the glaciers and glacial lakes covered the land surface with a thin layer of drift. Irregularities and deep canyons in the western part of the Lake basin are filled with sediments, making the lake bottom smooth. In contrast, depressions in the eastern part of the Lake basin are not filled. The

eastern lake bottom has many irregular north-south submarine ridges and canyons.

While the glacial-lake water levels were receding, waves carved ancient lake terraces, resembling gigantic stair steps, into the shoreline. These wave-cut terraces show that the surface area of one of the ancient lakes which existed in the vicinity of these basins was very large. It covered an area greater than the total combined area of Lakes Superior, Michigan, and Huron. The wave-cut terrace of this ancient lake is now above present Lake Superior water levels. After the tremendous weight of continental glaciers was removed, isostatic rebound and tilting of the land surface elevated these terraces.

Several channels have drained the Lake Superior basin at different times. During periods when glacial ice filled most of the basin and closed the eastern outlets, surface meltwater was high and water flowed from the west end of the basin through the Brule and St. Croix River valleys into the Mississippi River. When the glaciers retreated and the eastern outlets were opened, water was lowered almost to present levels and flowed into Lakes Huron and Michigan through abandoned river valleys across the Upper Peninsula of Michigan or through the St. Marys River valley.

Outcropping sandstone layers in the St. Marys River form a natural weir that restricted the outflow of Lake Superior. Man has since controlled Lake Superior outflows, beginning in 1921 when engineers completed

construction of the Sault Ste. Marie control works across the rapids.

Lake Huron

Lake Huron receives outflow from Lake Superior through the St. Marys River, a channel 70 miles long. It also receives outflow from Lake Michigan through the Straits of Mackinac. At its maximum depth of 752 feet, the lake extends 173 feet below sea level.

Three predominant rock formations command the Lake Huron basin topography from north to south. Near the north shore, which is the southern margin of the Canadian Shield, is a low, south-facing escarpment of Precambrian formations. The second escarpment is a ridge of Silurian age limestone and dolomite, called the Niagaran Escarpment, that forms Manitoulin Island and Saugreen Peninsula. This ridge parallels the north shore of Lake Huron and separates the main body of the Lake from the North Channel and Georgian Bay.

The third escarpment is a submerged but prominent ridge, roughly parallel to the Saugreen Peninsula and Manitoulin Island, that extends across the Lake from Alpena, Michigan, to Kincardine, Ontario. The deepest waters of the Lake occur in irregular depressions north of this ridge. South of this ridge the lake bottom is smoother. Saginaw Bay is southwest of the ridge.

Land and lake bottom topography south of the Canadian Shield features many ridges and valleys with sedimentary rock formations and modifications

resulting from erosion. The outcrop pattern of the formations resembles concentric circles with their centers in the central part of the Lower Peninsula of Michigan. These formations dip gently toward central Michigan, making a bowl-shaped structural feature called the Michigan Basin.

During the Ice Age, continental glaciers deepened preglacial lowlands, gouged out softer rock formations on the north and east sides of the Michigan Basin, and formed Lake Huron. The moving glaciers stripped soil from the rock surfaces and exposed the Niagaran Escarpment that is prominent throughout the Great Lakes area. Retreating glaciers filled depressions with glacial drift and glacial lake deposits, and carved glacial-lake terraces into the shoreline.

The outflow from Lake Huron passes through an outlet channel composed of the St. Clair and Detroit Rivers and Lake St. Clair. There are no artificial controls in the channel between Lakes Huron and Erie, but dredging operations in this watercourse over the years have made a deeper channel, with a substantial lowering of the water levels of Lakes Michigan and Huron. The St. Clair River carries Lake Huron outflow 27 miles into Lake St. Clair with a fall of five feet.

Lake Michigan

Lake Michigan is in the west Central portion of the Great Lakes Basin, south of Lake Superior and west of Lake Huron. It is connected to Lake Huron by the Straits of Mackinac.

Direction of currents in the Straits alternates from east to west

depending upon barometric pressure and wind conditions. The net flow, however, is eastward. Northern outflow goes into Lake Huron. A southern outflow of 3,200 cfs is diverted into the Mississippi River basin at Chicago.

The physiography of the Lake Michigan basin results from glacial deposits. Bedrock exposures are not common. Lake Michigan is bounded on the west and north by the Niagaran Escarpment, which dips under the Lake toward its basin. The relatively smooth slope of the lake bottom from the shore to the depths on the west and northwest sides of the Lake is essentially a dip-slope on the Niagara carbonate rocks.

The lake bed has four regions: a smooth basin to the south; a northern basin; and a submarine ridge and valley province to the northeast. The smooth area has a maximum depth of 564 feet and resembles a huge bowl with gently sloping sides. The bottom materials consist of sand along the shore, gravel between the 50 and 100-foot depth, and mud below the deep water. These sediments fill depressions and smooth the lake bottom. The divide is a large mid-lake area less than 400 feet deep. This shallow area of the lake bottom consists of two limestone ridges overlain by coarse sediments. Thin beds of sand have been found on the east shoreline down to the 120-foot depth, and on the west shoreline to depths ranging from 50 to 300 feet. The northern basin contains ridges and valleys trending northeast-southwest. The deepest point in the Lake, 925 feet deep, is in this region.

The submarine ridge and valley province are northeast of the northern basin. In this area the bottom has numerous deep troughs of 250 to 500 feet, separated by ridges with only 25 to 50 feet of water over them. Most of the valleys and ridges have a north-south orientation, with greater depths toward the south and southwest where this province merges with the northern basin.

At the basin's western end is Green Bay. The Door Peninsula, formed by the Niagara Escarpment, divides the embayment from the Lake. Water depths vary from an average of 75 feet to a maximum of 160 feet. Mud deposits cover the deeper floors. Sandy deposits, broken by bedrock outcrops, cover the shoreline slopes that extend various distances under the water.

A relatively shallow shelf starts approximately 45 miles west of the outlet of Lake Michigan and extends eastward through a narrow canyon in Lake Huron. It is an ancient river valley that now forms the major part of the Straits of Mackinac. A variety of sediments covers the bottom of this area.

Lake Michigan was formed during the Ice Age when continental glaciers gouged out the Lake Michigan lowland, and removed the overburden and softer rock formations, leaving ridges of harder, more resistant rock. When the glaciers retreated, they buried the rock outcrops and filled many of the valleys and troughs with glacial till, outwash and glacial lake sediments. A major outlet for the ancient glacial lakes in the Lake Michigan basin was near Chicago. Water flowed

south of the basin through the Illinois River valley into the Mississippi River. This natural outlet no longer exists because of the lower postglacial levels of the Lake. Enormous quantities of beach sand and sand dunes have accumulated along the shore at the south end of the Lake.

Lake St. Clair

The Michigan courts officially define Lake St. Clair as a Great Lake. These courts assert the rights and interests of the State of Michigan as proprietor and trustee of the water and submerged lands of Lake St. Clair. The lake has a surface area of 430 square miles and a natural maximum depth of 21 feet. It is 26 miles long, with marshy shores and a gently sloping bottom. Situated in glacial deposits, the lake has ridges of glacial till (moraines to the north and the south.)

The St. Clair River from Lake Huron flows into Lake St. Clair from the north. A small delta marks the north central and northwest area of the lake. The Detroit River drains Lake St. Clair and empties into Lake Erie, falling approximately three feet in 32 miles.

Lake Erie

Lake Erie is south of Lake Huron and southwest of Lake Ontario. Its surface area is 9,910 square miles, approximately one-thirteenth of the area of Lake Superior. It is the only Lake in the system whose point of greatest depth is above sea level. From the shallows in the western end, the bottom slopes eastward to a maximum depth of 210 feet.

The Lake Erie basin is divided into three areas. The western basin is relatively shallow and covered with fine sediments. The Detroit River discharge produces a flow pattern that penetrates far south into Lake Erie's western basin, and is traceable eastward through the northern islands area into the central basin. The western basin is underlain by hard limestone and dolomite that resist erosion. There are many shallow areas, ridges and islands. Most of the central and eastern basins were excavated in soft, easily-eroded shales of Devonian age. Part of this lake bottom is a resistant Devonian limestone. Although the rock in the two basins was similar, glaciers excavated the eastern basin deeper than the central. A submerged ridge of sand and gravel separates the central basin from the eastern.

Nearly 6,300 square miles in area, the central basin of Lake Erie is the largest of the three basins. It has a smooth, flat bottom. The eastern basin is a deepened extension of the central one. Glacial erosion deposits cover adjacent shorelands and deeper lake bottom areas. Occasional sand deposits are found along the shores.

The northern and western boundaries of the Lake Erie drainage basin are transitional and poorly defined. The obvious southeastern boundary adjoins the Appalachian Plateau.

Lake Erie discharges primarily at its eastern end, through the 37-mile Niagara River into Lake Ontario. More than one-half of the 326 foot fall from Lake Erie to Lake Ontario occurs at Niagara Falls, where the river crosses the Niagaran Escarpment. Lake Erie

water is also diverted into Lake Ontario through the Welland Canal.

Lake Ontario

Lake Ontario's water surface is approximately 245 feet above sea level. The lake is approximately 804 feet deep at its deepest location, where the bottom is 561 feet below sea level, lower than the bottom of any of the other Lakes except Lake Superior.

The Lake Ontario basin is a lowland bordered on the north by an escarpment of the Canadian Shield, on the east by the Adirondack Mountains, on the south by the Appalachian Plateau, and on the west by the Niagaran Escarpment. The Niagaran Escarpment is 200 feet high at Niagara Falls, but its height decreases as the escarpment stretches eastward, parallel to the south shore of Lake Ontario, until

it becomes inconspicuous near Rochester, New York, approximately 70 miles from Niagara Falls.

Lake Ontario has a long east-west axis. The lake bottom slopes gradually southward from the north shore, across more than two-thirds of the Lake. The bottom formation then rises abruptly to the south shores. During the ice ages, continental glaciers crossed the area and gouged out beds of soft shale to form the lake depression. The depth of scour and shape of the depression were influenced by hard limestone formations along the north shore of the Lake, extending over the sloping lake bottom nearly to the south shoreline. The retreating glaciers deposited sediments into the Lake and along its shoreline. The Lake Ontario outflow is discharged into the St. Lawrence River at its northeast end.

St. Lawrence River

The St. Lawrence River is the natural outlet for the Great Lakes. It flows from Lake Ontario across the St. Lawrence Plain into the Gulf of St. Lawrence. This plain is a lowland between the Adirondack Mountains and the Canadian Shield. The broad, multiple-channel river head is broken into small land areas and is called the Thousand Islands Area. East of this area, the river channel narrows abruptly where it flows across the hard, resistant rock protrusion of the Canadian Shield. The river outlet is a long, horn-shaped passage which opens into the Gulf of St. Lawrence.



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Great Lakes Basin Hydrology

The precipitation, water supplies, and outflows for the lakes are provided in Table 3. Precipitation data include the provisional values for the past month and the year-to-date and long-term averages. The provisional and long-term average water supplies and outflows are also shown.

**Table 3
Great Lakes Hydrology¹**

PRECIPITATION								
BASIN	AUGUST				YEAR-TO-DATE			
	1992 [*]	AVG. ^{**}	DIFF.	% OF AVG.	1992 [*]	AVG. ^{**}	DIFF.	% OF AVG.
Superior	3.6	3.2	0.4	112	19.5	19.5	0.0	100
Michigan-Huron	3.3	3.1	0.2	106	19.7	20.6	-0.9	96
Erie	3.8	3.2	0.6	119	26.5	23.6	2.9	112
Ontario	4.0	3.1	0.9	129	25.8	22.9	2.9	113
Great Lakes	3.5	3.1	0.4	113	21.3	21.0	0.3	101

LAKE	AUGUST WATER SUPPLIES ^{***}		AUGUST OUTFLOW ³	
	1992 ²	AVG. ⁴	1992 ²	AVG. ⁴
Superior	106,000	101,000	81,000	84,000
Michigan-Huron	98,000	55,000	181,000 ⁵	195,000
Erie	3,000	-12,000 ^{***}	218,000 ⁵	207,000
Ontario	49,000	8,000	275,000	253,000

^{*}Estimated (inches)

^{**}1900-90 Average (inches)

^{***}Negative water supply denotes evaporation from lake exceeded runoff from local basin.

¹Values (excluding averages) are based on preliminary computations.

²Cubic Feet Per Second (cfs)

³Does not include diversions

⁴1900-89 Average (cfs)

⁵Reflects effects of ice/weed retardation in the connecting channels.

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