A REPORT ON 1999 WATER LEVELS OF THE GREAT LAKES AND THE ST. LAWRENCE RIVER

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1.0 INTRODUCTION

This report describes the water levels in the Great Lakes - St. Lawrence River system in 1999. It also provides an assessment of hydrologic data collected by other agencies. Water level elevations are in metres above sea level at Rimouski, Quebec, on the International Great Lakes Datum (IGLD) of 1985. River flows are in cubic metres per second (m^3/s). The geographic area covered in the report extends from Lake Superior to Montreal on the St. Lawrence River.

2.0 THE GREAT LAKES - ST. LAWRENCE SYSTEM

The Great Lakes - St. Lawrence River basin, including land and lake surface, covers an area more than one million square kilometres (see Figure 1). As shown in Figure 2, the Great Lakes comprise a series of natural reservoirs positioned in a step-wise manner, with Lake Superior as the highest step and Lake Ontario the lowest. Lakes Michigan and Huron are considered one lake in hydraulic terms, because they are connected by the wide and deep Straits of Mackinac and stand at the same elevation.

Water levels fluctuate according to the climate of the region. Over-lake precipitation, evaporation and runoff are the main factors that affect water levels. Other factors include flow retardation due to ice in winter, and aquatic vegetation in the lakes' outlet rivers in the summer. Weather disturbances cause short-term fluctuations in water level. Human impacts include regulation of lake outflows, dredging of outlet channels, water diversions and consumption of water.

Lakes Superior and Ontario are the two lakes that have their outflows regulated by structures at their outlets. The outflows of the un-regulated lakes are dependent on their water levels. For Lakes Michigan-Huron and Lake St. Clair, their outflows through the St. Clair - Detroit River system depend also to a minor extent on the levels of Lake Erie due to backwater effect on these rivers. Ice jams in the St. Clair - Detroit River system, though infrequent, can cause large variations in the water level of Lake St. Clair.

Water level fluctuations on Lake Ontario do not affect the level of Lake Erie, as the two lakes are separated by the cascades and Niagara Falls in the Niagara River.

Lake St. Lawrence is that part of the St. Lawrence River extending from Iroquois to Cornwall, Ontario. The hydropower dam at Cornwall, located about 160 kilometres downstream of Lake Ontario, is used to regulate Lake Ontario's outflow. Several factors affect the water level on Lake St. Lawrence. They include: Lake Ontario level, flow at the hydropower dam at Cornwall, ice in the river between Lake Ontario and the dam, and winds.

Lake St. Francis extends from Cornwall to its outlets at the Beauharnois and Cedars hydro and navigation installations. Large water level fluctuations on Lake St. Francis are rare because Lake St. Francis is regulated within a narrow range by Hydro Quebec's control works. Besides the inflows from upstream and operations at the Beauharnois-Cedars installations, factors that affect Lake St. Francis levels are local runoff, winds, and ice on Lake St. Francis.

Lake St. Louis is located a short distance upstream of Montreal, at the confluence of the St. Lawrence River and the Ottawa River. Due to its relatively small area, the water level of Lake St. Louis can rise rapidly following snow melt on the Ottawa River basin and other local tributaries. Local runoff during heavy rain can also raise the levels rapidly.

Like Lake St. Louis, water levels at Montreal are affected by flows from Lake Ontario, the Ottawa River, local runoff and, in addition, downstream ice conditions. Winds and tides also affect the level in the harbour but to a lesser extent.

3. HYDROLOGIC CONDITIONS IN 1999

3.1 Weather Conditions

Regional weather conditions continued warmer than normal in 1999. But they seemed to settle down after 1998 that saw record high average air temperatures for most of Ontario, the January ice storm in eastern Ontario and western Quebec, and a wild swing of water supplies to the lower Great Lakes. The low water supply conditions in 1998 extended through 1999 and kept lake levels below average, and on some lakes, well below the levels of 1997 and 1998.

The snowstorms that hit southern Ontario in January 1999 brought with them some promise of an end to the dry conditions. However, that promise was soon broken, as rainfall and snowfall amounts through the rest of the winter fell to values that were well below normal.

Air temperatures across the Great Lakes basin were above normal throughout most of 1999. Only August failed to be a notably warm month. Overall the year ended about 1.5 degrees above normal, warm enough to make 1999 (preliminary) the second warmest year on record at most Canadian locations.

The ice season for the winter of 1998-99 was very short, due to the mild air temperatures and absence of severe cold weather systems. The winter of 1999-2000 started about the same way with warm weather and water conditions extending into December 1999. At the end of 1999, the shores of the Great Lakes and the St. Lawrence River remained virtually ice-free.

3.2 Precipitation

On average, about 820 millimetres (mm) of precipitation falls on the Great Lakes basin each year. Readings from about 100 precipitation stations scattered throughout the basin (excluding the St. Lawrence River) are used to measure precipitation. The density of stations is greater in the lower Great Lakes, and less in the upper Great Lakes region.

Table 1 compares the 1999 monthly Great Lakes basin precipitation with long-term averages since 1900. The comparison is also shown graphically in Figure 3. The total precipitation for 1999 was about 840 mm, which was marginally above average, however, it was not uniformly distributed. A lake-by-lake comparison is included in Table 1.

In 1999, the Lake Superior basin received 112% of average precipitation. February, May, July, September and October had above average precipitation while March and November were very dry. The Lakes Michigan-Huron basin precipitation in 1999 was about average, while that on the Lake Erie basin was 91% of average. On the Lake Ontario basin, precipitation was 96% of average, with the dry summer months offset by higher precipitation at the beginning and end of the year.

3.3 Water Supplies to the Great Lakes

While precipitation, which is often quoted, is one component in the water balance equation, net basin water supply is a better indicator of hydrologic conditions affecting lake levels. Net basin supply is the combined effect of over-lake precipitation, basin runoff and evaporation from the lake. The net total water supplies to a lake consist of the net basin supplies for the lake, and the inflow from upper lakes as applicable. The water supplies for the Great Lakes are computed in cubic metres per second for each month with 1999 values and those for 1997 and 1998, shown in Figures 4-7. Net basin supplies are shown for Lake Superior and Lakes Michigan-Huron. Since inflows from the upper lakes form a major part of the total supplies to Lake Erie and Lake Ontario, net total supplies for the two lower Great Lakes are shown.

As shown in Figure 4, net basin supplies to Lake Superior fell below average in the summer of 1997 and remained below average throughout 1998. These low supplies caused Lake Superior levels to drop to below average in the spring of 1998, and remain below average in 1999.

Like Lake Superior, the low Lakes Michigan-Huron water level conditions the past two years can be attributed to declining water supplies (Figure 5) since the fall of 1997. Except for January and July, water supplies to Lakes Michigan-Huron in 1999 were continually below average. March, August and October 1999 were exceptionally dry.

Total water supplies to Lake Erie (Figure 6), which includes inflow from Lakes Michigan-Huron, were below average in 1999. Like Lakes Michigan-Huron, August was particularly dry. As shown in Figure 7, net total water supplies to Lake Ontario were below average except in January and February when supplies were slightly above average. Both Figures 6 and 7 show that the water supply to the lower Great Lakes in 1999 was lower than in 1998 which, in turn, was lower than water supply in 1997. The above average water level conditions of two years ago has worked its way out of the Great Lakes system.

3.4 Water Levels and Outflows

Table 2 lists monthly mean water levels for the Great Lakes and several sites on the St. Lawrence River for 1999. The tables also show how these levels compare with historical data. The daily mean water levels are also shown graphically in Figures 8 to 15.

For Great Lakes water level comparisons, records since 1918 are used in accordance with the procedure agreed by Canadian and United States agencies. A network of gauges located around each lake is used to determine the mean daily and monthly water levels of the lakes. Water level records for Lake St. Lawrence, as measured at the gauge at the Long Sault dam, started in 1960 following completion of the St. Lawrence Seaway and power projects. Data at Pointe Claire, which measure the water levels on Lake St. Louis, extend back to 1915. For Montreal Harbour, data since 1967 are used following the most recent significant physical changes to that part of the river.

Outflows of the Great Lakes are determined by adding up the flows through various structures and channels at the lakes' outlets. These include hydropower plants, navigation locks, and water diverted for industrial and domestic uses. On the un-regulated lakes (Lakes Michigan-Huron, St. Clair and Lake Erie), stage-discharge equations based on current meter measurements are also used in conjunction with measured flows at the hydropower plants to determine the outflows of the lakes.

Lake Superior began 1999 at 24 cm below its seasonal average (Figure 8). The lake reached its minimum level for the year in March at an elevation of 183.06 m, 23 cm lower than one year earlier and 45 cm lower than in March 1997. The last time Lake Superior's level was this low in March was in 1927. Increased water supplies in the May–July period raised Lake Superior's levels faster than usual. Although the lake levels rose above chart datum in mid May, and remained above 1998 levels beginning in July, the levels were below average throughout 1999.

Lakes Michigan-Huron levels (Figure 9) were about 10 cm below average in early 1999. The dry supplies during the summer to early winter period moved the levels further below average. In November, the lakes were near chart datum at 40 cm below average and 85 cm lower than two years earlier. The last time Lakes Michigan-Huron levels were this low in November was in 1966. The levels were slightly below chart datum at the end of December.

Lake St. Clair and Lake Erie (Figures 10 and 11) were slightly above average in the first three months of 1999. In response to the low inflows from Lakes Michigan-Huron, their levels fell below average in May. In November, Lake Erie's level was 9 cm below average at elevation 173.91 metres. Similar to Lakes Michigan-Huron, the last time Lake Erie experienced levels this low in November was in 1966. At the end of December, both Lakes St. Clair and Erie were about 15 cm below average.

Lake Ontario (Figure 12) started the year about 24 cm below average. The January mean level was 74.32 m. The last time the January level was lower than this was in 1965. During 1999, Lake Ontario's levels were consistently below average. The levels peaked in July, about a month later than usual. The decline in the level the rest of the year was a bit slower than usual, due to slight increases in water supplies and low outflows.

As a matter of interest, between April 1998 and April 1999, the total reduction in the water levels on all the Great Lakes was equivalent to a loss of about 126 cubic kilometres (km^3) of water. This was the biggest twelve-month drop between two successive months of April for the period of record beginning 1918. This reduction in water volume is equivalent to the average flow over Niagara Falls, twenty-four hours a day, for 663 days. The second largest April-to-April drop, also in terms of water volume, was between 1930 and 1931 (112 km^3). The third largest April-to-April drop occurred between 1976 and 1977 (about 99 km^3) while that between 1987 and 1988 (83 km^3) ranks fourth. The all-time largest twelve-month drop was from October 1986 to October 1987 when the lakes' volume reduced by 137 km^3. Very large and rapid drops in the Great Lakes water levels do occur infrequently and the 1998-1999 conditions rank up near the top of historical recorded precedent.

If the comparisons are on a calendar year basis, then the 40 km^3 of reduction in water volume during 1999 would rank as the 14^{th} biggest drop in the period of record since 1918. The 91 km^3 reduction in 1998 ranks seond while the reduction during 1987 (116 km^3) ranks first.

Lake St. Lawrence is that part of the St. Lawrence River extending from Iroquois to the Moses-Saunders hydropower dam at Cornwall. Being immediately upstream of the hydropower dam which is used to regulate Lake Ontario outflows, Lake St. Lawrence levels are directly affected by flow variations through the dam. High outflows at the dam lower Lake St. Lawrence levels, and low flows have the opposite effect. The 1999 daily mean Lake St. Lawrence levels, as measured at the gauge at the Long Sault dam, are shown in Figure 13.

The Lake St. Lawrence water levels were very low for several days in mid January. This was caused by ice forming and accumulating just above the Iroquois Dam. This ice bridging restricted the flow through the Iroquois Dam, and caused a large headloss or slope of the river between Lake Ontario and Cornwall. Maintenance of low flows at the hydropower dam at Cornwall and a gradual erosion of the ice cover helped in the recovery of the Lake St. Lawrence levels by the end of January. Beginning in March and through the rest of the year, Lake St. Lawrence levels were higher than average due to low flows at the hydropower dam. In July, the level was at 73.80 m, about 30 cm higher than average. The last time the level was this high in July was in 1968. The 1999 summer levels were much higher than those of 1997 and 1998 when high flows at the dam caused low water levels on Lake St. Lawrence.

Lake St. Louis levels (Figure 14) were near average from January to April. The levels fell sharply after the Ottawa River freshet to below average in May through October. During the last three months of 1999, Lake St. Louis levels rose in response to increased tributary flows including the Ottawa River.

Water level fluctuations at the Port of Montreal closely resembled those of Lake St. Louis. New record monthly minimum levels occurred at the Port from May to October for the period of record beginning 1967. The August monthly level set a new record low for August for the period dating back to 1913.

Table 3 lists the 1999 monthly outflows from each of the Great Lakes. Lake Superior outflows for the year averaged 1940 m^3/s, or about 91 percent of average. The outflows from the middle lakes - Michigan-Huron and Erie were also below average. Lake Ontario's outflows were consistently low throughout the year, and, like Lake Superior, averaged about 91 percent of average for the year.

4.0 WATER MANAGEMENT RELATED TO WATER LEVELS

4.1 Lake Superior Regulation

Lake Superior's Regulation Plan 1977-A specifies monthly outflows from the lake based upon this lake's level and the level of Lakes Michigan-Huron downstream. The procedure of taking downstream lake levels into account is termed systemic regulation. Assessment of the hydrologic conditions on the upper Great Lakes and overseeing outflow regulation are the responsibilities of the International Joint Commission's Lake Superior Board. In normal operations, Lake Superior outflows are as specified by the regulation plan. Under certain conditions, the International Joint Commission (IJC) approves deviations from the regulation plan on the advice of the Board.

The outflow of Lake Superior is regulated by a number of structures in the St. Marys River at Sault Ste. Marie, Ontario and Sault Ste. Marie, Michigan. Water leaving Lake Superior flows through either the hydropower plants, navigation locks, or the St. Marys River compensating works. The 16-gated compensating works was built early in the century to offset the extra flow capacity added to the St. Marys River by the hydropower developments. This structure is located immediately upstream of the St. Mary's Rapids. The northern half of the structure with eight gates is owned and operated by Great Lakes Power Limited in Canada. The other half with the remaining eight gates is owned by the U.S. Army Corps of Engineers.

The IJC requires a minimum flow equivalent to one-half gate open at the compensating works in order to supply water to the main portion of the St. Marys Rapids. In addition, the most northerly gate is kept partially open to ensure a continuous supply of water to the fishery remedial channel. With the minimum one-half gate open setting in place, changes to Lake Superior's outflow are usually accomplished by adjusting the water diversions through the hydropower plants. If the hydropower plants cannot fully use the available water, the excess is released through the compensating works by opening additional gates.

During 1999, the outflows of Lake Superior were as specified by the regulation plan. There were no significant hydrologic events that required deviations from the regulation plan. A one-half gate open setting occurred at the compensating works in 1999, except for August and September when increases in Lake Superior outflows necessitated more gates open.

4.2 Lake Ontario Regulation

The outflow of Lake Ontario is regulated using the hydropower dam and spillway in the St. Lawrence River near Cornwall, Ontario and Massena, New York. Lake Ontario Regulation Plan 1958-D specifies weekly outflows based upon Lake Ontario's level and trends in water supplies. The regulation plan helps prevent water level extremes, both upstream on Lake Ontario, and downstream in the Montreal area, and it attempts to balance the interests of shoreline property owners, commercial navigation and hydropower interests.

Lake Ontario outflow regulation is overseen by the IJC's International St. Lawrence River Board of Control. In normal operations, the Lake Ontario outflow is as specified by the regulation plan. However, the Board has some discretionary authority to direct flow deviations from the regulation plan to provide benefit or relief from adverse impacts associated with water level and flow fluctuations. In recent years, the Board has also taken into consideration recreational boating and environmental interests in making its regulation decisions.

During 1999, the Lake Ontario outflow was as specified by the regulation plan with some deviations as described in the following three paragraphs:

On December 31, 1998, ice build-up in the St. Lawrence River below the Port of Montreal had raised and improved the water levels in the harbour such that higher Lake Ontario outflows to assist commercial navigation at the port was no longer necessary. A return to regulation plan flow was made at that time. As a result of previous outflow deviations from the regulation plan, mainly the higher outflows in November and December 1998 to provide assistance to the Port of Montreal, about 7 cm of water had been removed from Lake Ontario by the end of December in comparison to strict application of the regulation plan. To offset these deviations and restore this amount of water on Lake Ontario, outflows less than the regulation plan were made during the Ottawa River spring freshet.

Some minor deviations from the regulation plan also took place during the winter of 1998-99 to respond to changing ice conditions in the St. Lawrence River.

Follow the Ottawa spring freshet, the Board's objective was to conserve water in light of the low water level conditions on Lake Ontario. Due to the extremely low water levels downstream in the St. Lawrence River, it was not possible to reduce the Lake Ontario outflow to below regulation plan during the summer months. With the increase in Ottawa River and downstream tributary flows raising downstream levels starting in October, the St. Lawrence Board was able to marginally reduce Lake Ontario's outflow and retained about 4 cm of water on Lake Ontario by the end of December.

4.3 Activities by Environment Canada

Environment Canada continues to issue a monthly water level forecast for the Great Lakes and Montreal Harbour as a joint undertaking with the U.S. Army Corps of Engineers. A monthly newsletter is also published to update readers on water levels. The forecast bulletins and the newsletters are distributed each month by Fisheries and Oceans Canada in paper copy and on the Internet. In support of the International St. Lawrence River Board of Control, a weekly distribution of Lake Ontario and St. Lawrence River hydrologic data is made to subscribers on an E-mail list.

The department also issues monthly water level bulletins during the recreational boating season for locations on the St. Lawrence River downstream to Lake St. Louis. The bulletin is distributed to local media, shore property owners and marinas to advise of water level and flow conditions on the river.

Environment Canada provides technical support to the IJC's Boards in the regulation of the outflows of Lake Superior and Lake Ontario, as discussed in Sections 4.1 and 4.2.

Environment Canada continues to be active in studies of climate change impacts on the Great Lakes and water levels. In 1999, departmental staff also participated in several International Joint Commission studies. These included the Great Lakes water consumption, diversion and bulk water removals Reference, and a plan of study to evaluate current IJC criteria governing the regulation of Lake Ontario.

Finally, the department worked with provincial and private hydropower utilities and navigation agencies on the Y2K issue to ensure a transition into the new millennium without problems that might affect Great Lakes water quantity management operations.

5.0 EFFECTS OF WATER LEVEL FLUCTUATIONS

5.1 Shore Property

There were no reports of serious flood or erosion damage on the Great Lakes and the St. Lawrence River in 1999. This can be attributed to the relatively low water levels and an absence of severe storms throughout the year.

In October and November 1998, the low and declining Lake Ontario level generated a great deal of concern among those residents who rely on shore-wells for water supply. Telephone calls to Environment Canada came mainly from Wolfe Island, Howe Island and a few other communities near Kingston. In 1999 the number of calls was much less. This can be attributed to the fall of 1999 levels being generally 10-20 cm higher than those of a year earlier. It is likely that problems and inconvenience persisted for some residents who had low water levels in their shore-wells.

As noted earlier, water levels as low as those in 1999 have not been experienced by many shore property owners since these levels have not occurred in the past 30 years. For some, especially those living in newer developments, the rapid change in water levels over the past three years was probably a surprise. There were concerns expressed by owners who cannot use their boat ramps on the property, but complaints about unsightly exposed shoreline were noticeably absent. The low water levels provided owners an opportunity to repair their shore protection works and other installations.

The costs for pumping municipal and industrial water supplies were probably higher in 1999. The magnitude of this impact cannot be determined without a comprehensive survey and analysis.

Lake St. Lawrence was the only area in the Great Lakes - St. Lawrence system that experienced well above average water level conditions in 1999 due to its unique location. However, the levels throughout the year were well below flood stage.

5.2 Commercial Navigation

The opening and closing of the navigation season on the Great Lakes including the Welland Canal took place on schedule and without problems related to water levels or ice. The low water levels during the year, however, caused some traffic delays and affected shippers who had to reduce vessel loads.

Problems associated with low water levels occurred at the Port of Montreal. It was reported that some in-coming vessels had to off-load prior to entering the port, and some were not able to take full loads on departure. Record low water levels occurred during the summer months. Rain during the October-December period in the Montreal region and Ottawa River basin raised levels in the harbour above chart datum for the balance of the year.

5.3 Recreational Boating

Except for Lake St. Lawrence, recreational boaters on the Great Lakes and the St. Lawrence River including Lake St. Louis experienced well below average water level conditions in 1999. The problems related to low levels included un-useable docks and ramps, reduced accessibility while on the lakes and rivers, increased frequency of hull and propeller damage, and a shortened boating season. Most of the concerns came from the Thousand Islands area of the St. Lawrence River and from Georgian Bay.

5.4 Hydropower Generation

Due to the low water levels, hydropower generation in 1999 was less than average, and much less than production in 1997 and 1998 when levels and flows were higher.

The hydropower facilities in the St. Marys River used the full amounts of water specified by the regulation plan for power generation except for some short periods when repairs reduced their capacities.

The flows in the Niagara River were slightly above average in the first half of 1999, and slightly below average in the second half. Hydropower generation at Niagara Falls was near average for the year. The Moses-Saunders power dam and the Beauharnois-Cedars installations had below average hydropower production due to low flows in the St. Lawrence River.

6.0 FORECAST OF FUTURE WATER LEVEL CONDITIONS

Water levels of the Great Lakes fluctuate according to weather conditions. Since it is not possible to accurately forecast weather conditions several months in advance, forecasts are made assuming average, wet and dry weather conditions for the next six months.

Assuming average water supplies, the levels of Lakes Michigan-Huron are forecast to remain well below seasonal average for the next six months. Lakes Superior and Ontario levels are expected to approach but remain below average in early 2000. Lakes St. Clair and Erie are expected to remain slightly below average with average water supplies. Should warm and dry conditions again prevail, the water levels of all the lakes can be expected to fall further below average. If above average water supplies are received, a recovery to near average level conditions can be expected.

The precipitation received regionally over the winter and the spring freshet will provide an early indication of water level conditions to be expected in the Great Lakes later in 2000.

7.0 SUMMARY AND CONCLUSIONS

Great Lakes water levels in 1999 were below average as a result of the low water supplies to the lakes which began in 1997 on the upper lakes. The last time levels were this low was in the mid 1960s. Some moderate water level rebounds occurred on Lake Superior and Lake Ontario but they, like the other lakes, remained below average at year end.

The drops in the water level of the Great Lakes in 1998 and 1999, in terms of water volume, were among the largest on record since 1918.

Montreal Harbour levels experienced record low levels during the summer months, due to a combination of very low flows from Lake Ontario, the Ottawa River and other local tributaries. Rainfall during the last three months of 1999 raised the harbour's level closer to seasonal average in December.

The year 1999, like 1998, saw relatively mild winter air temperatures over the Great Lakes basin. As a result, much less lake ice formed during in the winter of 1998-99. The 1999-2000 ice season began the same way and at the end of December 1999 most of the Great Lakes remained ice-free.

Preliminary data show that in 1999, the region experienced its second warmest year, following 1998 which was the warmest year.

Problems associated with low water levels in 1999 included reduced hydropower generation, reduced water depths for commercial navigation, un-useable recreational boating docks and ramps and reduced channel drafts on the lakes and rivers for all boaters. It is assumed there were additional costs related to water withdrawal for some domestic and industrial users.

The below-average water levels and absence of storms in 1999 resulted in reduced flood and erosion damage on the shores of the Great Lakes. Occasional low water levels as experienced in 1999 are considered beneficial in promoting diversity in plants and wildlife in Great Lakes wetlands.

Given the water level conditions at the end of 1999, the risk of serious shoreline flood and erosion damage in 2000 should remain very low. Should dry conditions continue to prevail, low water supplies and low water level conditions in 2000 could cause considerable concern to Great Lakes-St. Lawrence River basin interests.

Table 1 Comparison of 1999 Great Lakes Basin Precipitation and Long-Term Average (millimetres)

Superior Basin

	1999	Percentage of average	Average 1900-1998	Previous Maxima and Minima (Year of Occurrence) Maximum	Minimum
Jan	51	102	50	91 (1935)	22 (1961)
Feb	56	151	37	84 (1939)	11 (1993)
Mar	29	66	44	102 (1979)	10 (1910)
Apr	41	82	50	106 (1960)	17 (1949)
May	93	135	69	129 (1970)	21 (1948)
Jun	81	98	83	151 (1943)	23 (1910)
Jly	122	147	83	142 (1952)	28 (1936)
Aug	94	116	81	186 (1988)	26 (1930)
Sep	124	139	89	164 (1941)	33 (1967)
Oct	92	131	70	140 (1995)	16 (1947)
Nov	39	61	64	120 (1985)	11 (1939)
Dec	40	77	51	90 (1984)	9 (1913)
Sum	862	112	770		

Michigan-Huron Basin

	1999	Percentage of average	Average 1900-1998	Previous Maxima and Minima (Year of Occurrence) Maximum	Minimum
Jan	85	157	54	95 (1997)	20 (1956)
Feb	40	91	44	86 (1908)	14 (1969)
Mar	18	33	55	117 (1998)	15 (1958)
Apr	74	112	66	126 (1929)	26 (1946)
May	75	100	75	142 (1983)	31 (1925)
Jun	100	127	79	144 (1969)	29 (1988)
Jly	115	151	76	132 (1952)	30 (1936)
Aug	70	89	79	136 (1972)	24 (1927)
Sep	85	97	88	213 (1986)	30 (1979)
Oct	58	81	72	147 (1954)	14 (1924)
Nov	40	57	70	128 (1985)	19 (1904)
Dec	65	110	58	106 (1971)	14 (1913)
Sum	825	101	820		

Erie Basin

	1999	Percentage of average	Average 1900-1998	Previous Maxima and Minima (Year of Occurrence) Maximum	Minimum
Jan	96	155	62	160 (1950)	14 (1961)
Feb	48	91	53	117 (1990)	10 (1987)
Mar	40	57	70	171 (1913)	11 (1910)
Apr	106	133	80	152 (1961)	24 (1946)
May	78	93	84	176 (1943)	17 (1934)
Jun	67	77	87	168 (1937)	19 (1988)
Jly	59	70	84	190 (1992)	29 (1930)
Aug	54	67	81	180 (1975)	33 (1969)
Sep	68	85	80	176 (1926)	19 (1908)
Oct	62	89	70	196 (1954)	11 (1924)
Nov	63	88	72	192 (1985)	10 (1904)
Dec	68	102	66	160 (1990)	21 (1943)
Sum	809	91	890		

Table 1 (continued)

Ontario Basin

	1999	Percentage of average	Average 1900-1998	Previous Maxima and Minima (Year of Occurrence) Maximum	Minimum
Jan	138	200	69	137 (1978)	28 (1981)
Feb	33	55	60	112 (1971)	23 (1969)
Mar	74	109	68	143 (1936)	18 (1915)
Apr	40	55	73	127 (1929)	29 (1915)
May	47	60	78	145 (1943)	16 (1920)
Jun	66	85	78	159 (1972)	30 (1912)
Jly	66	84	79	160 (1992)	32 (1933)
Aug	73	91	80	142 (1977)	32 (1907)
Sep	111	135	82	159 (1945)	24 (1964)
Oct	74	96	77	212 (1955)	13 (1963)
Nov	92	116	79	168 (1927)	15 (1904)
Dec	51	69	73	140 (1990)	27 (1943)
Sum	865	96	900		

Great Lakes Basin

	1999	Percentage of average	Average 1900-1998	Previous Maxima and Minima (Year of Occurrence) Maximum	Minimum
Jan	84	150	56	100 (1950)	22 (1961)
Feb	45	100	45	80 (1908)	17 (1969)
Mar	30	55	55	111 (1976)	15 (1910)
Apr	66	103	64	106 (1929)	29 (1915)
May	77	103	75	116 (1983)	33 (1934)
Jun	86	106	81	121 (1968)	36 (1910)
Jly	104	132	79	124 (1992)	32 (1936)
Aug	74	93	80	128 (1977)	29 (1930)
Sep	96	110	87	166 (1986)	39 (1948)
Oct	70	97	72	127 (1954)	21 (1924)
Nov	49	70	70	137 (1985)	18 (1904)
Dec	57	96	59	92 (1983)	17 (1913)
Sum	838	102	820		

Source: Preliminary data provided by NOAA, Corps of Engineers compiled from stations in the U.S. and Canada

Table 2 Great Lakes Monthly Mean Water Levels in 1998 and 1999 and Their Comparison with Previous Records (Metres, IGLD-1985)

Lake Superior

	1998	1999	Average 1918-1998	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum	Minimum
Jan	183.40	183.12	183.36	183.70 (1986)	182.83 (1926)
Feb	183.33	183.10	183.30	183.63 (1986)	182.76 (1926)
Mar	183.29	183.06	183.26	183.61 (1986)	182.74 (1926)
Apr	183.35	183.12	183.29	183.68 (1986)	182.72 (1926)
May	183.34	183.20	183.39	183.74 (1986)	182.76 (1926)
Jun	183.39	183.31	183.47	183.76 (1986)	182.85 (1926)
Jul	183.41	183.43	183.54	183.82 (1950)	182.96 (1926)
Aug	183.38	183.47	183.56	183.86 (1952)	183.02 (1926)
Sep	183.33	183.44	183.57	183.86 (1985)	183.12 (1926)
Oct	183.26	183.38	183.54	183.91 (1985)	183.10 (1925)
Nov	183.21	183.32	183.50	183.89 (1985)	183.01 (1925)
Dec	183.19	183.24	183.43	183.81 (1985)	182.92 (1925)

Lakes Michigan-Huron

	1998	1999	Average 1918-1998	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum (Year of Occurrence)	Minimum
Jan	176.74	176.27	176.36	177.18 (1987)	175.60 (1965)
Feb	176.71	176.28	176.34	177.11 (1986)	175.59 (1964)
Mar	176.74	176.24	176.36	177.12 (1986)	175.58 (1964)
Apr	176.89	176.25	176.45	177.23 (1986)	175.61 (1964)
May	176.91	176.28	176.55	177.28 (1986)	175.74 (1964)
Jun	176.90	176.34	176.61	177.33 (1986)	175.76 (1964)
Jul	176.88	176.40	176.64	177.39 (1986)	175.78 (1964)
Aug	176.79	176.36	176.62	177.39 (1986)	175.77 (1964)
Sep	176.68	176.24	176.57	177.38 (1986)	175.76 (1964)
Oct	176.55	176.14	176.50	177.50 (1986)	175.70 (1964)
Nov	176.44	176.04	176.44	177.38 (1986)	175.65 (1964)
Dec	176.36	175.99	176.40	177.26 (1986)	175.62 (1964)

Lake St. Clair

	1998	1999	Average 1918-1998	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum	Minimum
Jan	175.45	175.10	174.85	175.80 (1986)	173.88 (1936)
Feb	175.47	174.99	174.79	175.80 (1986)	173.89 (1926)
Mar	175.52	174.95	174.91	175.80 (1986)	174.05 (1934)
Apr	175.61	175.05	175.06	175.82 (1986)	174.32 (1926)
May	175.63	175.05	175.14	175.83 (1986)	174.42 (1934)
Jun	175.58	175.10	175.19	175.92 (1986)	174.45 (1934)
Jul	175.56	175.12	175.21	175.93 (1986)	174.50 (1934)
Aug	175.48	175.07	175.17	175.90 (1986)	174.41 (1934)
Sep	175.35	174.96	175.10	175.84 (1986)	174.34 (1934)
Oct	175.19	174.85	175.01	175.96 (1986)	174.27 (1934)
Nov	175.00	174.75	174.93	175.82 (1986)	174.18 (1934)
Dec	174.93	174.70	174.93	175.80 (1986)	174.24 (1964)

Table 2 (Continued)

Lake Erie — Previous Recorded Maxima & Minima (Year of Occurrence)

	1998	1999	Average 1918-1998	Maximum		Minimum	
Jan	174.61	174.00	174.00	174.86	(1987)	173.21	(1935)
Feb	174.66	174.11	173.99	174.78	(1987)	173.18	(1936)
Mar	174.74	174.18	174.07	174.88	(1986)	173.20	(1934)
Apr	174.85	174.26	174.22	174.98	(1985)	173.38	(1934)
May	174.87	174.29	174.31	174.97	(1986)	173.44	(1934)
Jun	174.77	174.28	174.34	175.04	(1986)	173.45	(1934)
Jul	174.71	174.23	174.32	175.03	(1986)	173.45	(1934)
Aug	174.60	174.15	174.26	174.94	(1986)	173.43	(1934)
Sep	174.46	174.05	174.17	174.83	(1986)	173.38	(1934)
Oct	174.29	173.97	174.07	174.94	(1986)	173.30	(1934)
Nov	174.12	173.91	174.00	174.85	(1986)	173.20	(1934)
Dec	174.04	173.87	173.99	174.90	(1986)	173.19	(1934)

Lake Ontario — Previous Recorded Maxima & Minima (Year of Occurrence)

	1998	1999	Average 1918-1998	Maximum		Minimum	
Jan	74.82	74.32	74.56	75.16	(1946)	73.81	(1935)
Feb	75.06	74.43	74.59	75.27	(1952)	73.78	(1936)
Mar	75.15	74.50	74.67	75.37	(1952)	73.94	(1935)
Apr	75.42	74.63	74.88	75.65	(1973)	74.03	(1935)
May	75.35	74.71	75.01	75.73	(1973)	74.11	(1935)
Jun	75.18	74.78	75.04	75.76	(1952)	74.19	(1935)
Jul	75.14	74.81	74.99	75.66	(1947)	74.14	(1934)
Aug	74.93	74.73	74.88	75.58	(1947)	74.00	(1934)
Sep	74.73	74.58	74.74	75.41	(1947)	73.91	(1934)
Oct	74.51	74.47	74.62	75.22	(1945)	73.82	(1934)
Nov	74.34	74.43	74.54	75.18	(1945)	73.75	(1934)
Dec	74.29	74.47	74.53	75.20	(1945)	73.74	(1934)

Lake St. Lawrence — Previous Recorded Maxima & Minima (Year of Occurrence)

	1998	1999	Average 1960-1998	Maximum		Minimum	
Jan	73.18	72.78	72.85	73.62	(1967)	71.78	(1977)
Feb	73.04	72.88	72.39	73.32	(1983)	71.38	(1978)
Mar	72.80	73.12	72.74	73.42	(1966)	71.58	(1993)
Apr	73.57	73.38	73.53	73.94	(1962)	73.16	(1972)
May	73.08	73.64	73.64	74.00	(1973)	73.02	(1987)
Jun	73.08	73.75	73.58	73.96	(1966)	72.98	(1987)
Jul	73.10	73.80	73.50	73.92	(1967)	72.84	(1987)
Aug	72.81	73.62	73.34	73.90	(1967)	72.78	(1987)
Sep	72.77	73.45	73.17	73.90	(1967)	72.74	(1985)
Oct	72.78	73.39	73.08	73.78	(1962)	72.62	(1997)
Nov	72.99	73.47	73.01	73.72	(1962)	72.64	(1997)
Dec	73.11	73.52	73.06	73.66	(1962)	72.54	(1981)

Table 2 (Continued)

Lake St. Louis

	1998	1999	Average 1915-1998	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	21.39	21.05	21.20	21.61	(1952)	20.39	(1934)
Feb	21.51	21.16	21.18	21.97	(1978)	20.33	(1936)
Mar	22.03	21.14	21.20	22.12	(1973)	20.35	(1965)
Apr	22.18	22.42	21.60	22.45	(1951)	20.54	(1965)
May	21.84	20.74	21.59	22.55	(1974)	20.51	(1964)
Jun	21.61	20.72	21.33	22.46	(1947)	20.39	(1965)
Jul	21.64	20.72	21.17	22.01	(1973)	20.44	(1965)
Aug	21.41	20.63	21.03	21.81	(1972)	20.19	(1934)
Sep	21.28	20.65	20.96	21.74	(1986)	20.12	(1934)
Oct	21.09	20.77	20.95	21.81	(1986)	20.11	(1934)
Nov	20.80	20.85	20.98	21.86	(1986)	20.07	(1934)
Dec	20.76	20.92	21.06	21.80	(1986)	20.32	(1935)

Montreal Harbour

	1998	1999	Average 1967-1998	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	6.78	6.11R	6.91	8.96	(1968)	6.18	(1992)
Feb	6.87	6.46	7.11	9.04	(1967)	6.34	(1989)
Mar	7.56	6.41	7.12	8.36	(1973)	6.13	(1989)
Apr	8.21	6.86	7.61	8.82	(1976)	6.23	(1995)
May	7.05	5.67R	7.39	8.93	(1974)	6.13	(1995)
Jun	6.75	5.56R	6.83	8.12	(1974)	5.93	(1988)
Jul	6.84	5.52R	6.59	7.49	(1973)	5.66	(1988)
Aug	6.40	5.32R	6.47	7.27	(1972)	5.84	(1995)
Sep	6.21	5.44R	6.39	7.08	(1986)	5.64	(1995)
Oct	5.94	5.75R	6.44	7.16	(1986)	5.82	(1991)
Nov	5.55R	5.82	6.58	7.31	(1967)	5.55	(1998)
Dec	5.60R	6.05	6.63	7.24	(1972)	5.60	(1998)

Preliminary data based on a network of gauges on each lake.

Table 3 Outflows from the Great Lakes in 1998 and 1999 (cubic metres per second)

Lake Superior

	1998	1999	Average 1900-1998	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum	Minimum
Jan	1820	1560	1950	2630 (1971)	1250 (1922)
Feb	1800	1560	1920	2610 (1969)	1270 (1922)
Mar	1970	1570	1890	2690 (1969)	1290 (1982)
Apr	1940	1520	1950	2940 (1951)	1300 (1922)
May	2030	1550	2130	3450 (1951)	1250 (1931)
Jun	1800	2070	2200	3480 (1951)	1220 (1922)
Jul	1800	2180	2280	3570 (1938)	1270 (1922)
Aug	1590	2480	2360	3600 (1950)	1270 (1926)
Sep	1550	2450	2350	3570 (1950)	1160 (1955)
Oct	1560	2220	2300	3570 (1996)	1250 (1926)
Nov	1560	2020	2260	3740 (1985)	1250 (1981)
Dec	1560	2040	2060	3170 (1950)	1310 (1981)
Annual	1750	1940	2140		

Lakes Michigan-Huron

	1998	1999	Average 1900-1998	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum	Minimum
Jan	5480	4290	4510	6060 (1987)	3060 (1934)
Feb	5450	4980	4410	5720 (1974)	3000 (1942)
Mar	5490	4700	4850	5830 (1986)	3510 (1931)
Apr	5660	4950	5150	6260 (1986)	3600 (1901)
May	5660	4940	5380	6370 (1986)	4390 (1964)
Jun	5680	5030	5470	6430 (1985)	4420 (1964)
Jly	5700	5150	5530	6570 (1974)	4500 (1964)
Aug	5560	5210	5530	6630 (1986)	4530 (1964)
Sep	5600	5010	5490	6600 (1986)	4470 (1933)
Oct	5440	4930	5440	6740 (1986)	4420 (1933)
Nov	5280	4780	5380	6650 (1986)	4390 (1934)
Dec	5240	4730	5200	6230 (1986)	3990 (1935)
Annual	5520	4890	5200		

Table 3 (Continued)

Lake Erie

	1998	1999	Average 1900-1998	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	7050	5520	5640	7420	(1987)	4050	(1936)
Feb	6940	5750	5520	7050	(1987)	3340	(1936)
Mar	7280	5870	5690	7480	(1986)	4110	(1934)
Apr	7390	5960	5970	7700	(1974)	4390	(1935)
May	7270	6110	6240	7760	(1974)	4590	(1934)
Jun	7130	5780	6260	7820	(1986)	4560	(1934)
Jly	7060	5860	6160	7670	(1986)	4450	(1934)
Aug	6730	5510	6050	7420	(1986)	4470	(1934)
Sep	6520	5370	5940	7140	(1986)	4450	(1934)
Oct	6190	5340	5840	7450	(1986)	4420	(1934)
Nov	6010	5490	5840	7280	(1986)	4280	(1934)
Dec	5880	5560	5830	7620	(1985)	4330	(1934)
Annual	6790	5680	5910				

Lake Ontario

	1998	1999	Average 1900-1998	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	6830	5890	6310	8470	(1987)	4700	(1935)
Feb	8150	6700	6410	8310	(1997)	4360	(1936)
Mar	9490	6850	6720	9490	(1998)	5010	(1935)
Apr	8140	6750	7110	9200	(1973)	5070	(1964)
May	9640	6350	7370	10100	(1993)	4980	(1965)
Jun	8870	6250	7480	10010	(1993)	5350	(1965)
Jly	8750	6220	7410	9910	(1976)	5520	(1934)
Aug	8380	6290	7250	9340	(1974)	5300	(1934)
Sep	8050	6250	7060	9230	(1986)	5100	(1934)
Oct	7420	6160	6880	9170	(1986)	4960	(1934)
Nov	6690	6010	6760	9570	(1986)	4810	(1934)
Dec	6320	5920	6640	9260	(1986)	4810	(1934)
Annual	8060	6300	6950				

Source: Environment Canada, Ontario Region
December and Annual figures for 1999 are preliminary

Figure 1 Great Lakes - St. Lawrence River Basin

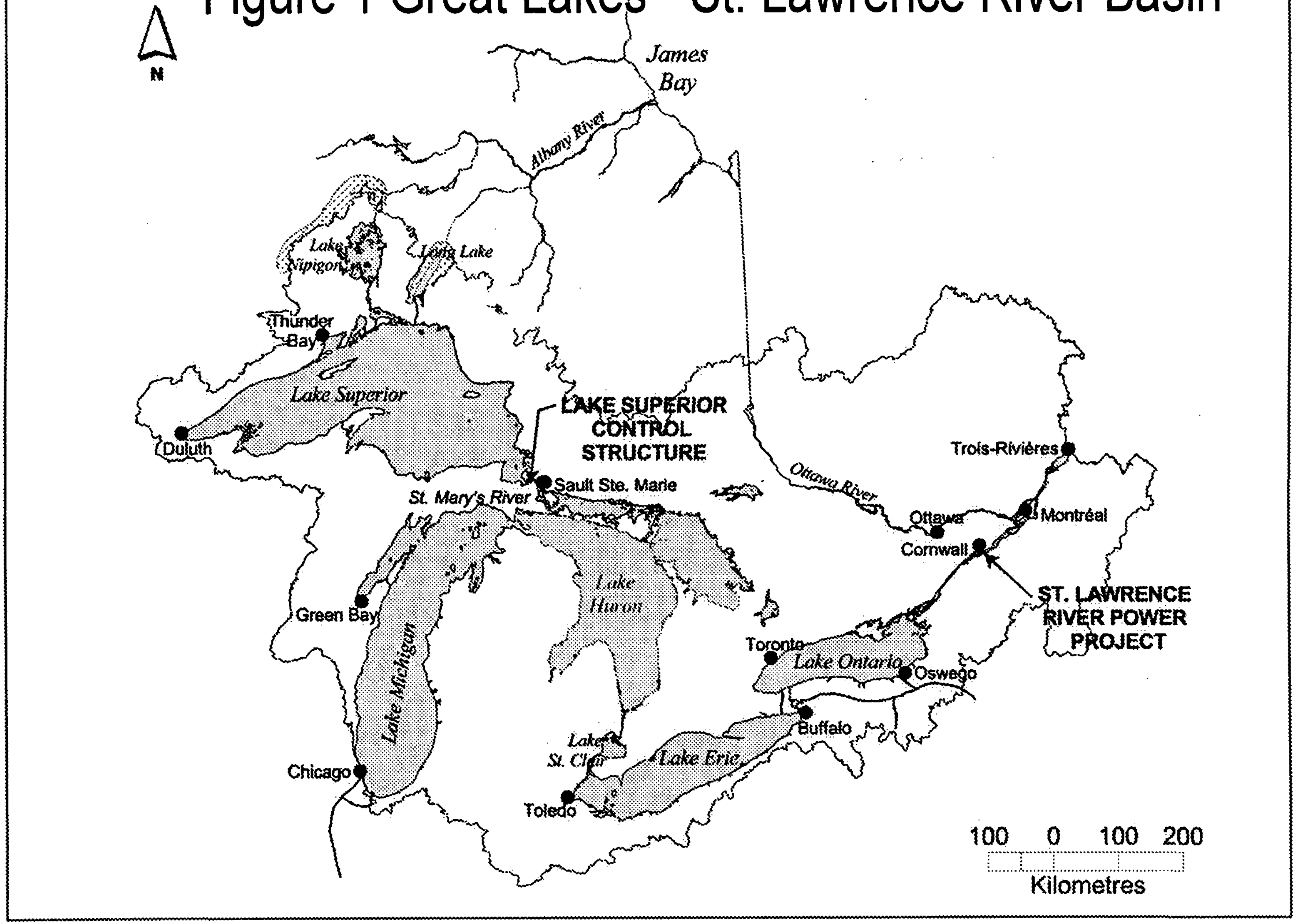


Figure 2 Water Surface Profile (at datum IGLD 1985)

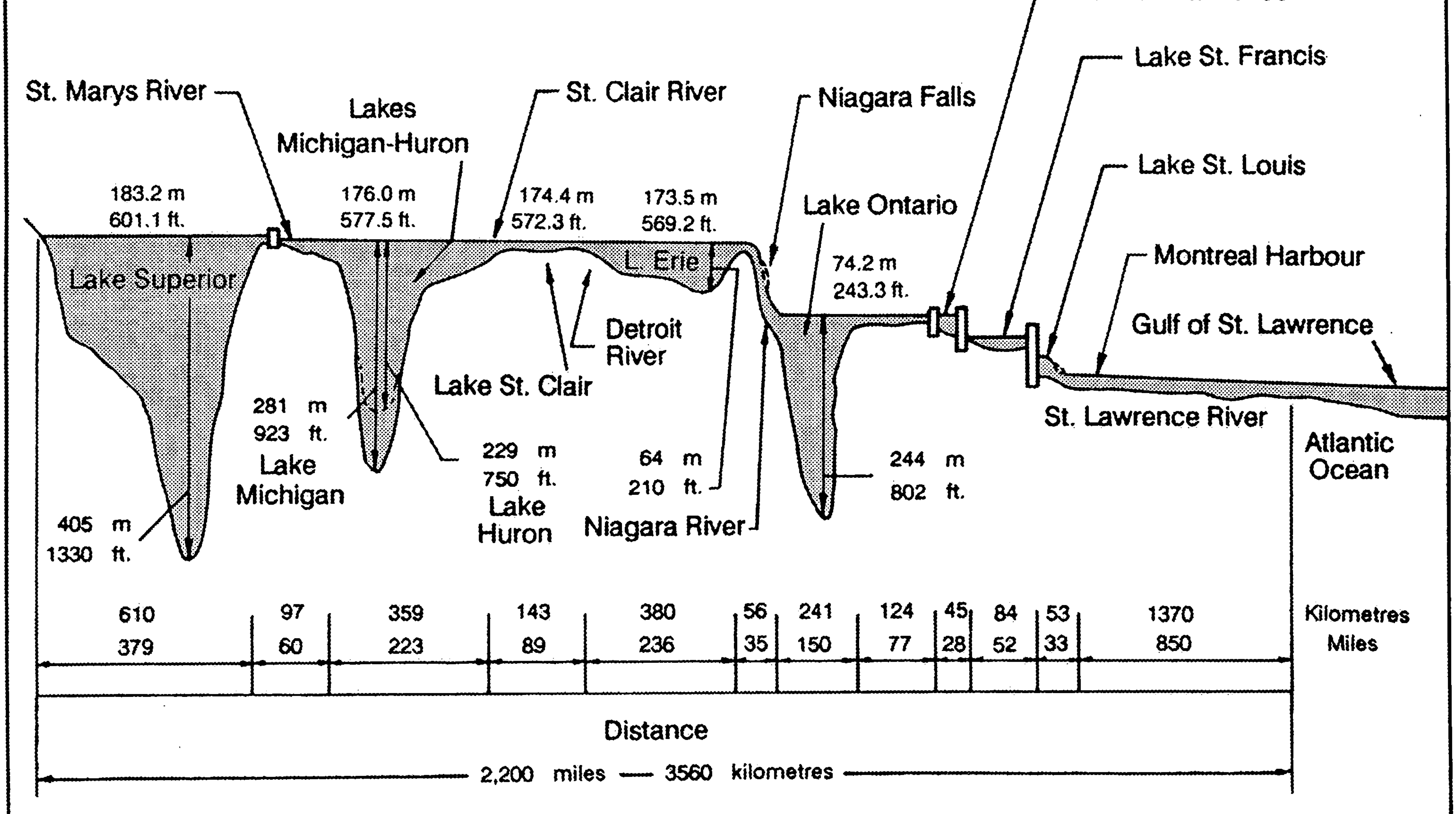


Figure 3 Great Lakes Basin Precipitation, m m

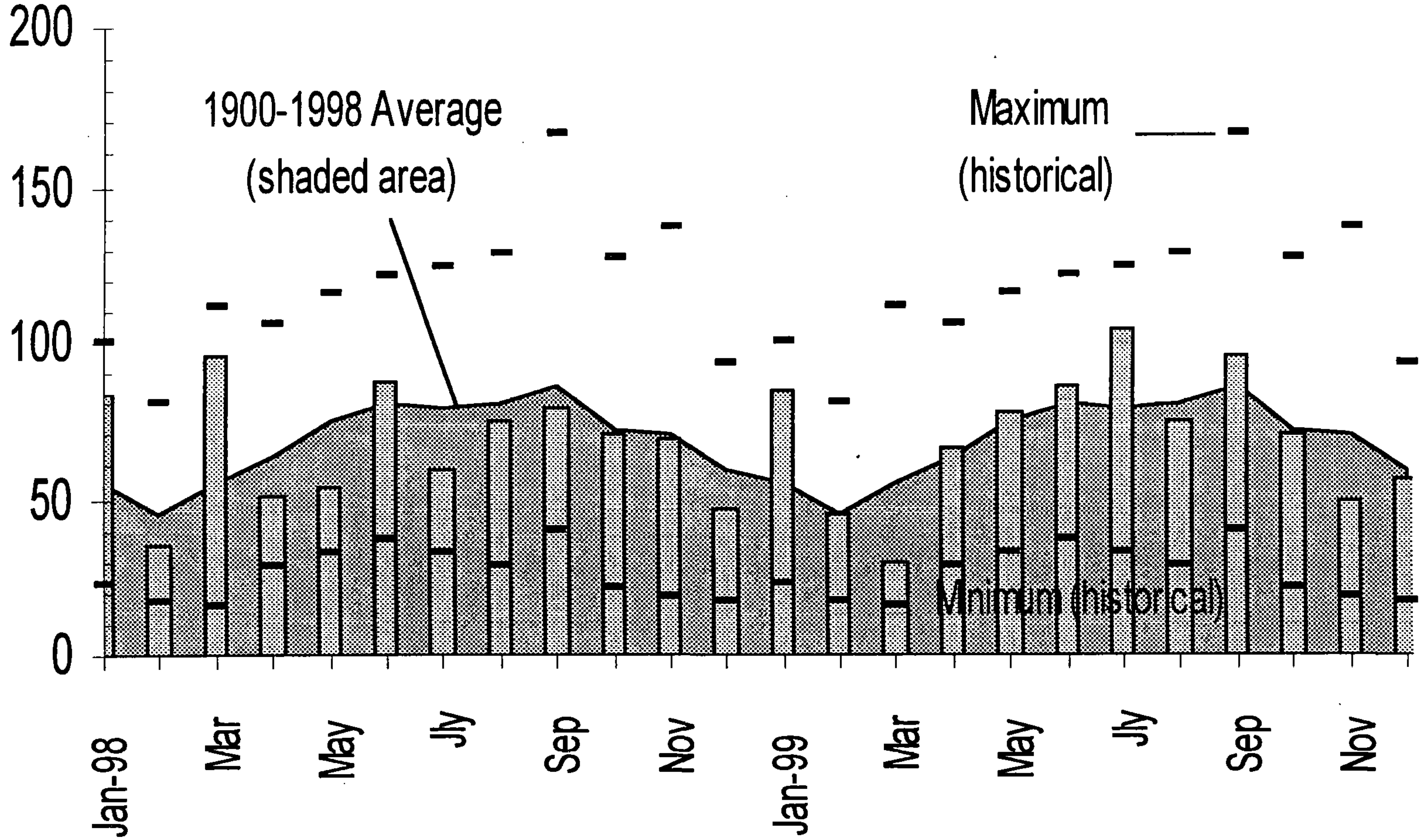


Figure 4 Lake Superior Monthly Net Basin Supplies (m^3/s)

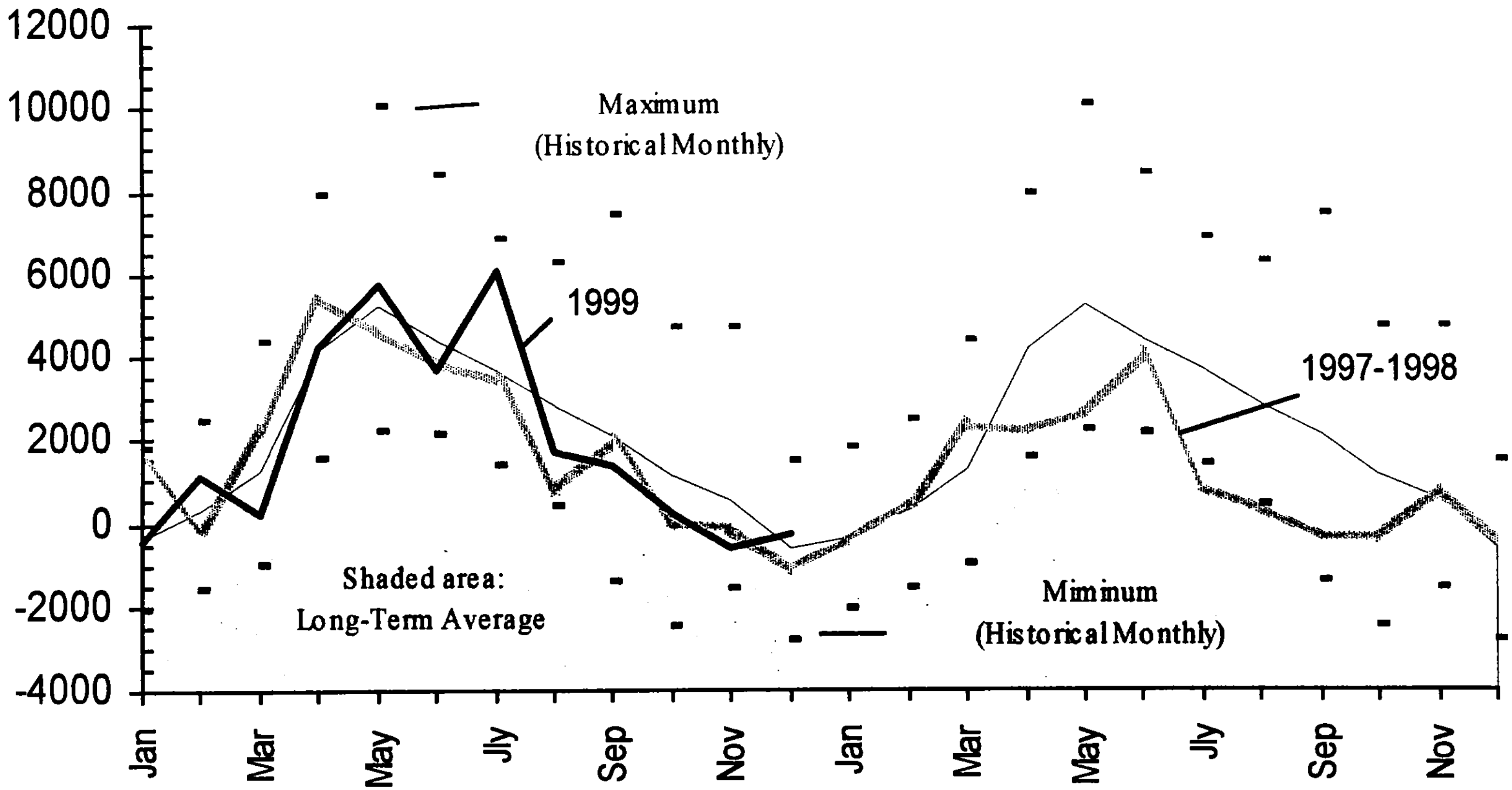


Figure 5 Lakes Mich-Huron Monthly Net Basin Supplies (m^3/s)

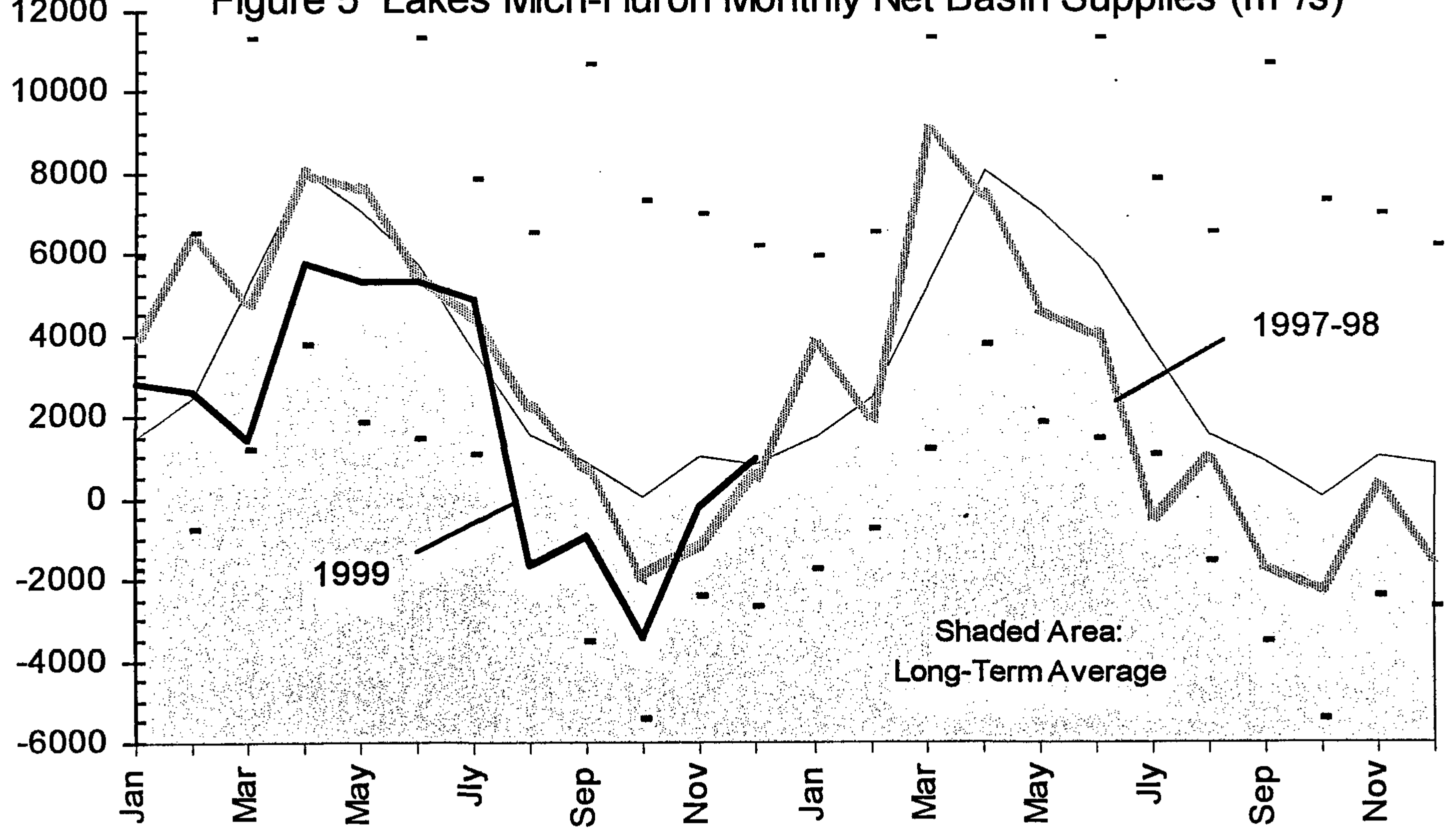


Figure 6 Lake Erie Net Total Supplies (m^3/s)

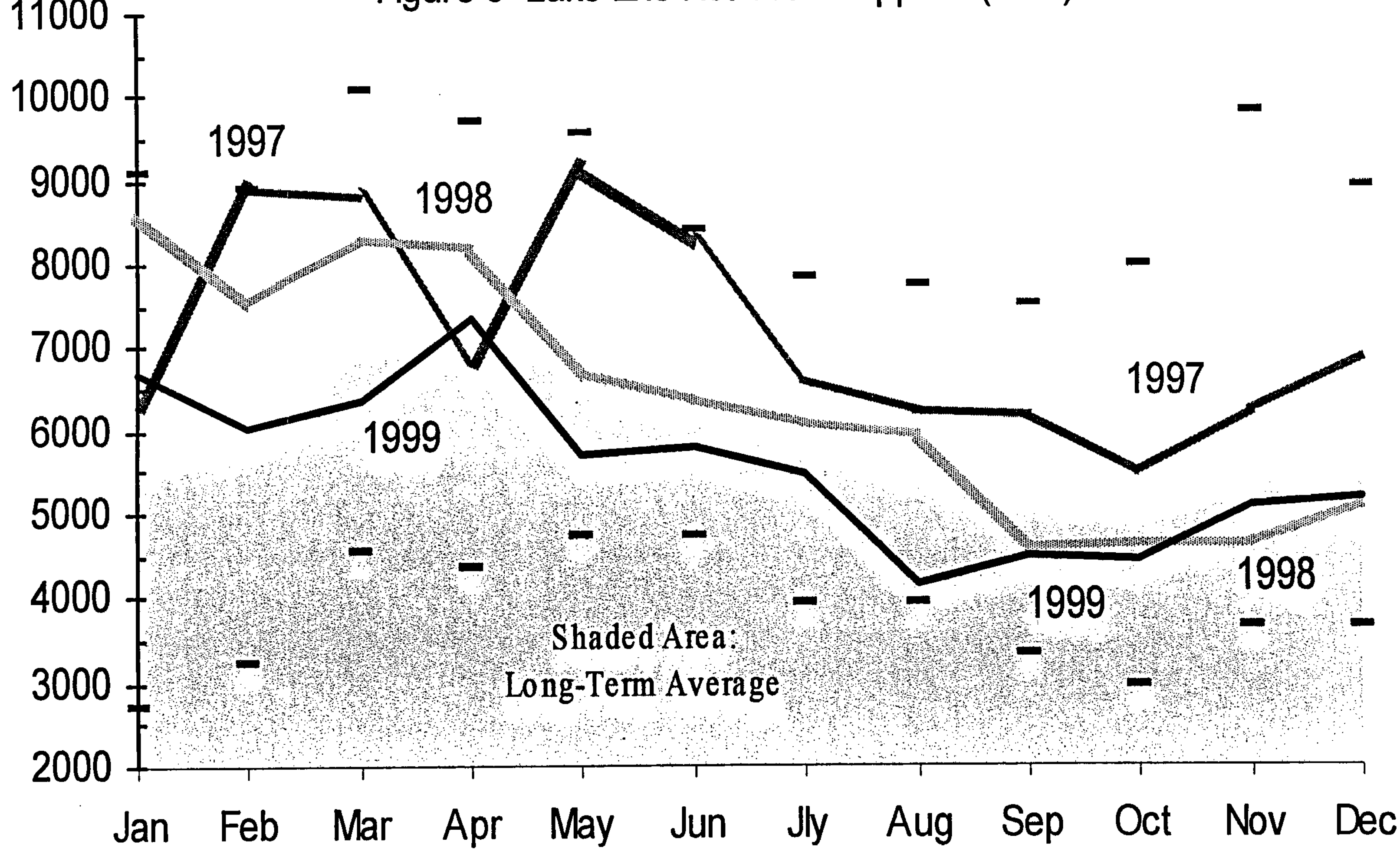
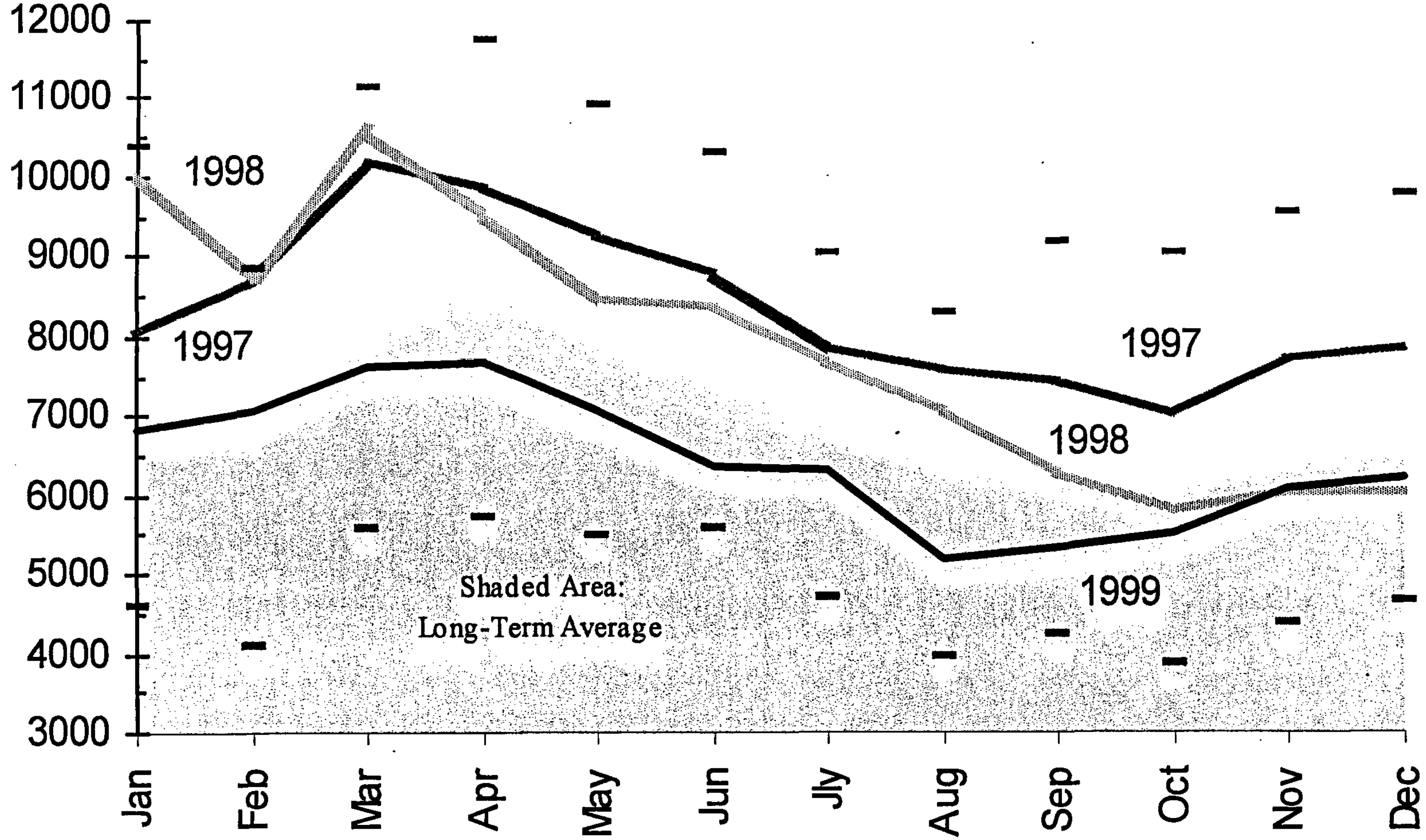


Figure 7 Lake Ontario Net Total Supplies (m^3/s)



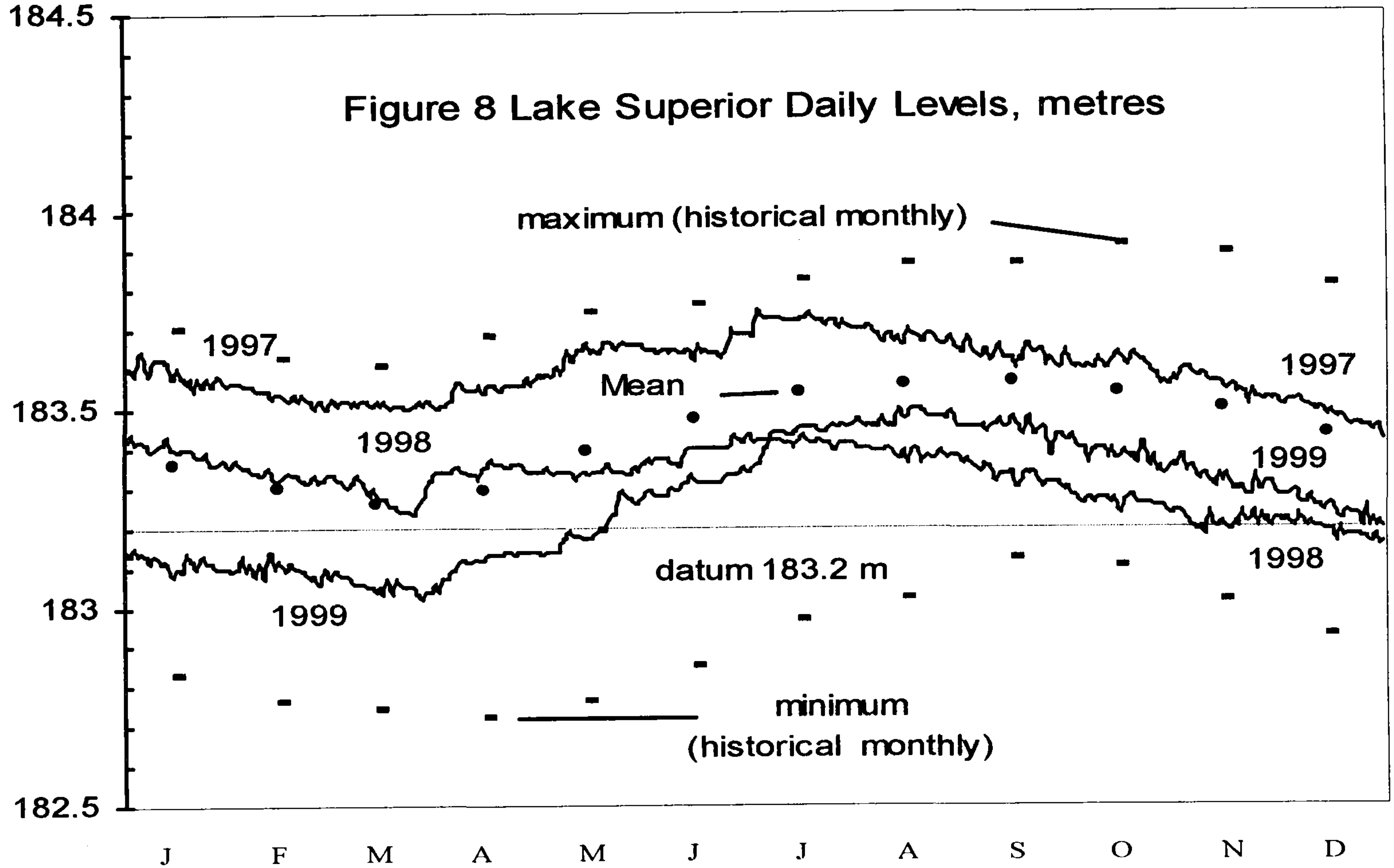

184.5
184
183.5
183
182.5
Figure 8 Lake Superior Daily Levels, metres
maximum (historical monthly)
1997
Mean
1998
1999
datum 183.2 m
minimum
(historical monthly)
J
F
M
A
M
J
J
A
S
O
N
D

Figure 9 Lakes Mich-Huron Daily Levels, metres

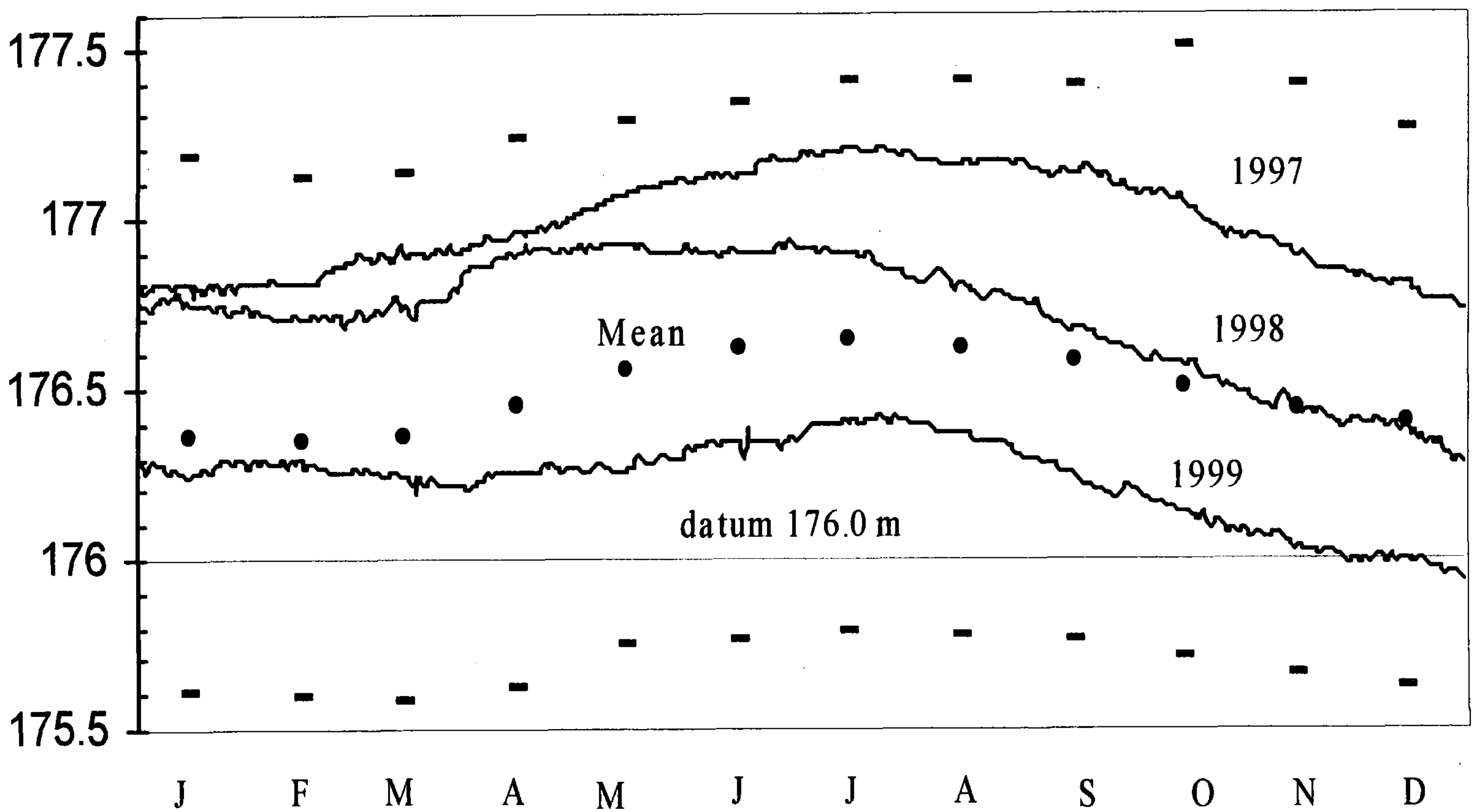


Figure 10 Lake St. Clair Daily Levels, metres

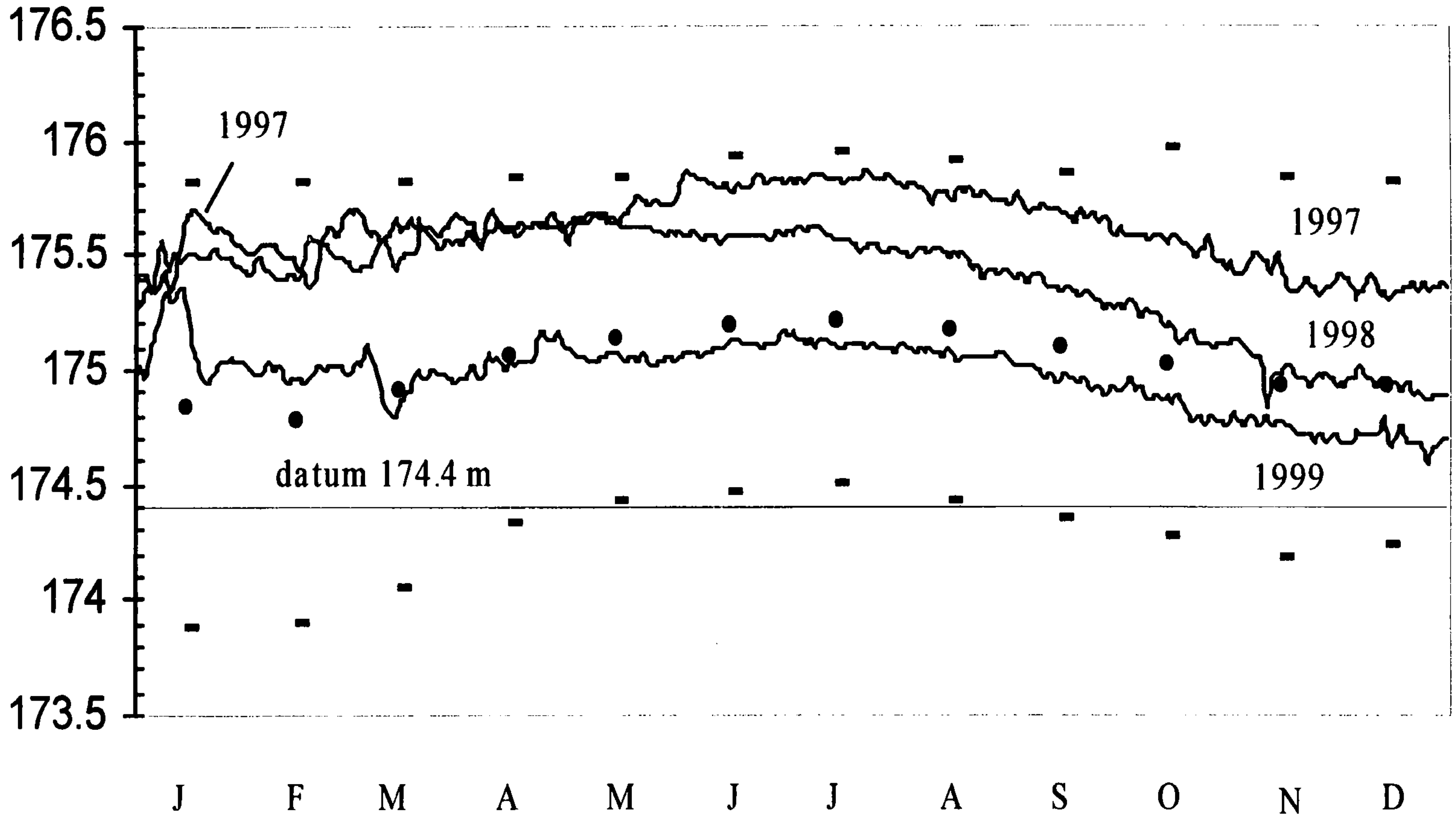


Figure 11 Lake Erie Daily Levels, metres

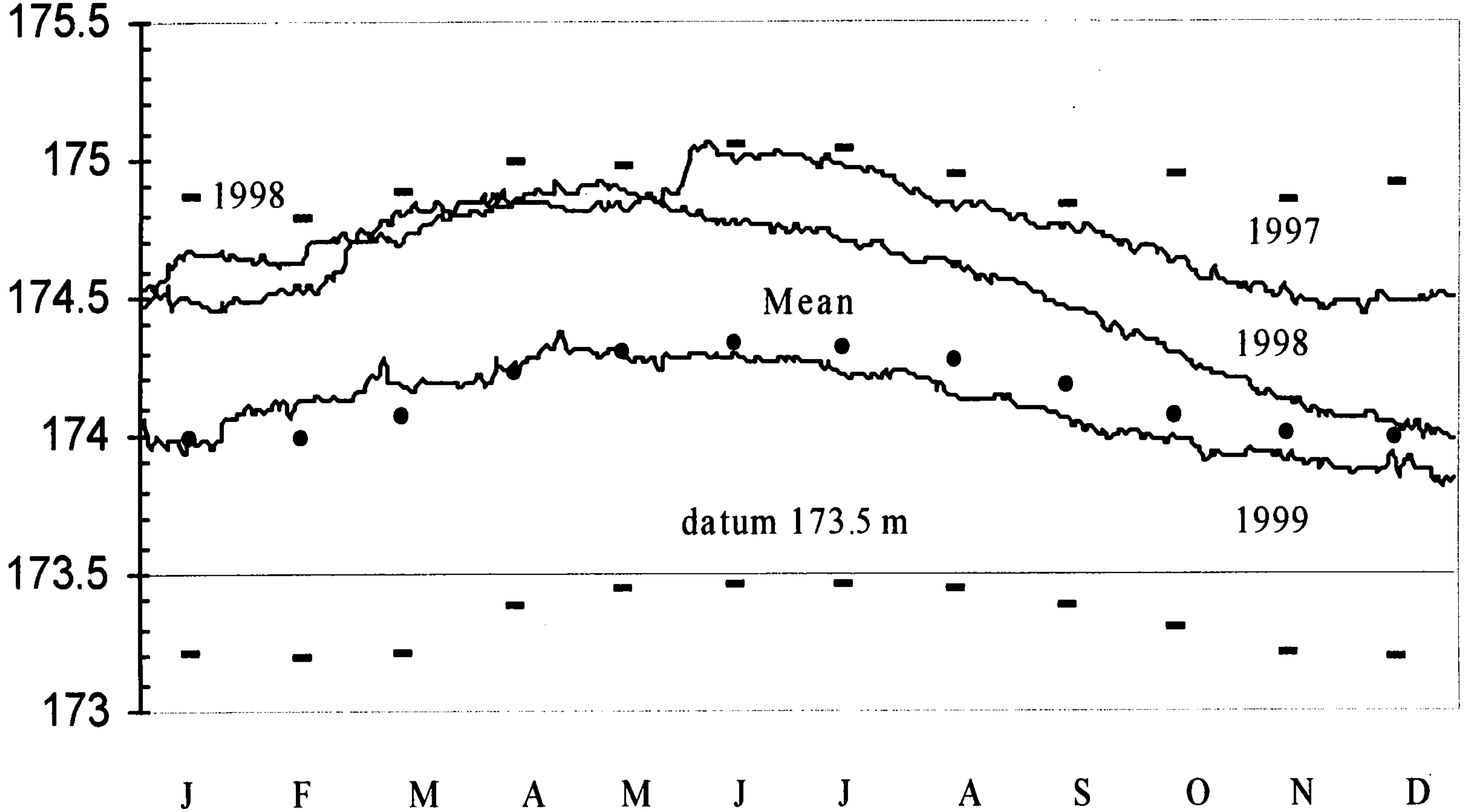


Figure 12 Lake Ontario Daily Levels, metres

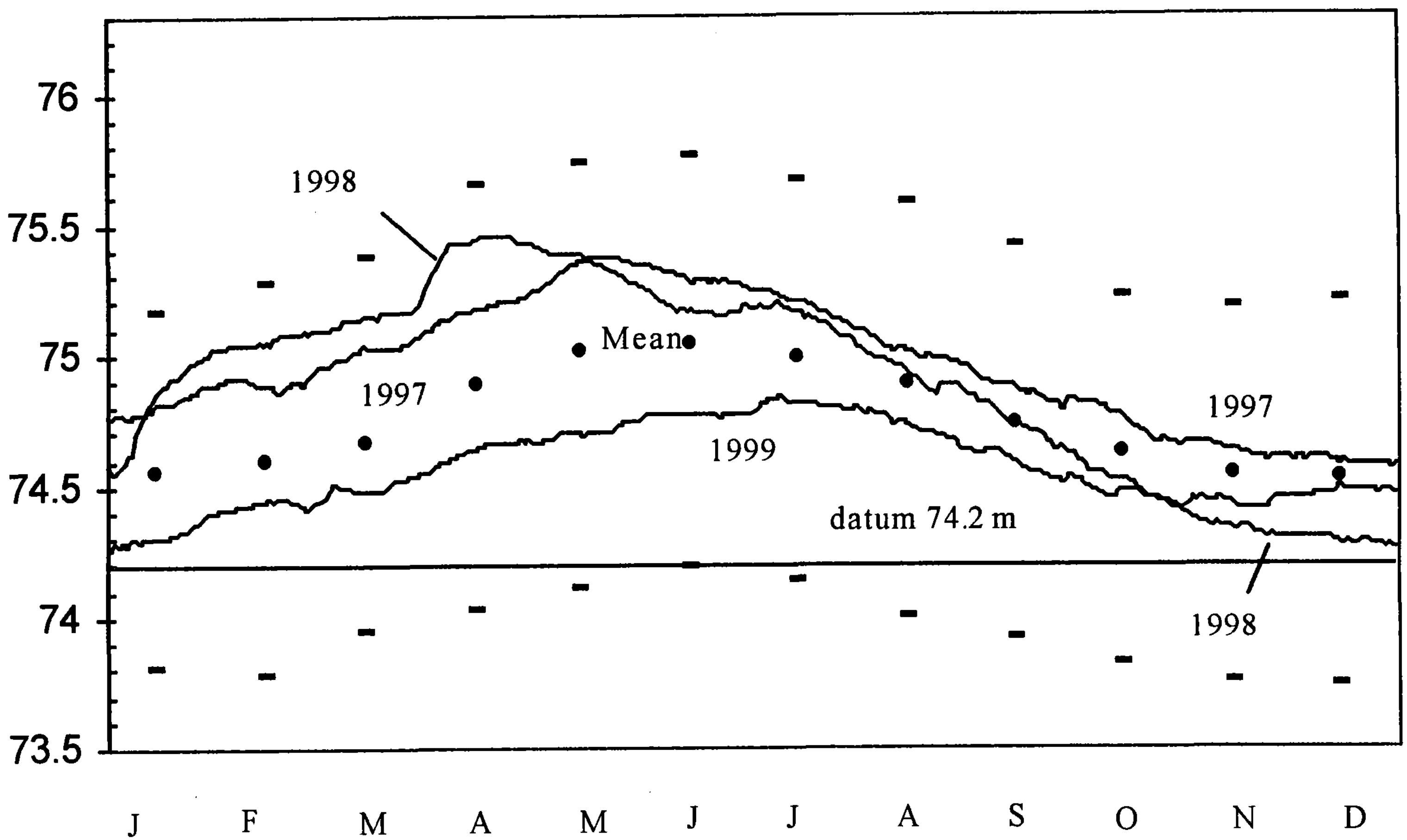


Figure 13 Lake St. Lawrence Daily Levels, metres

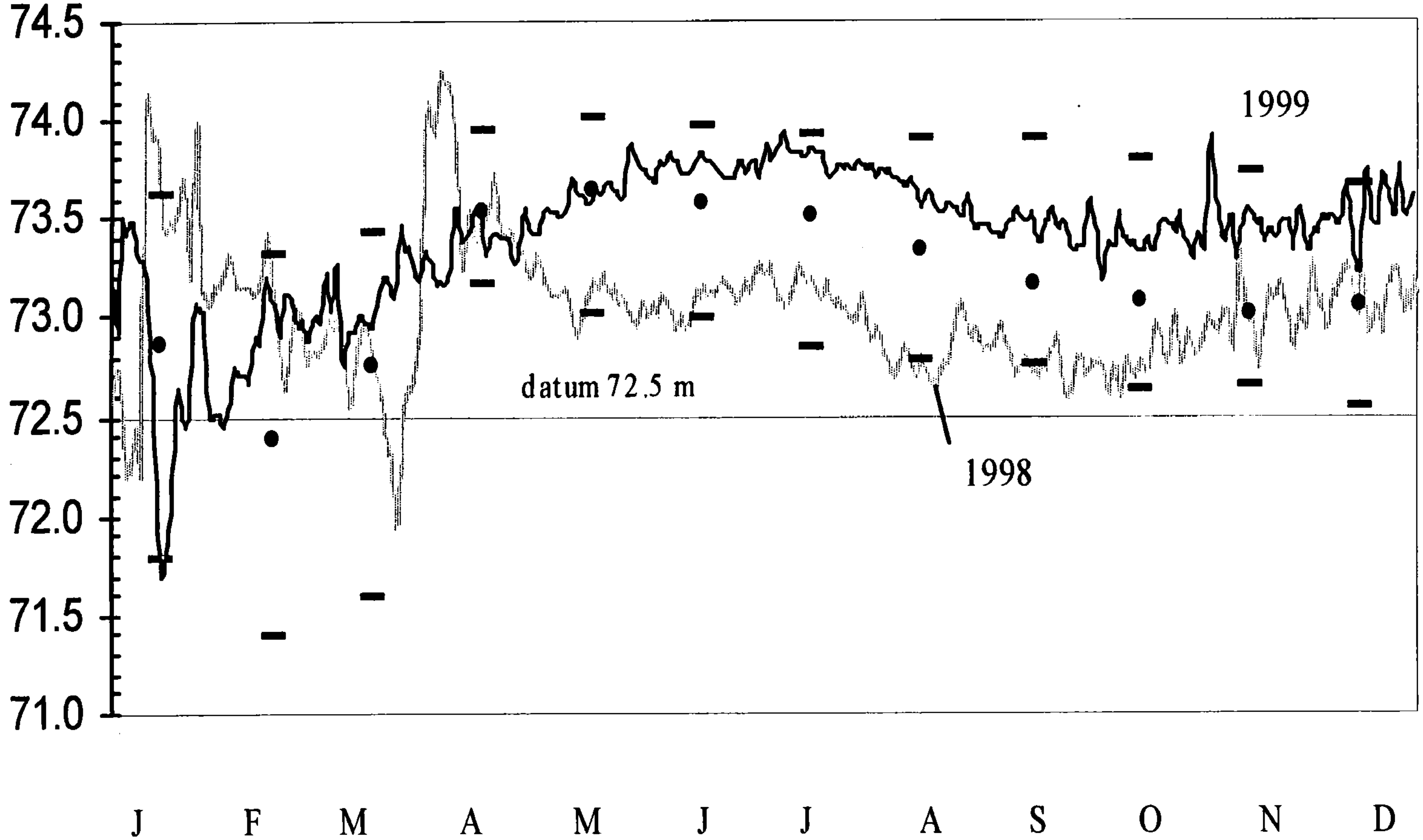


Figure 14 Lake St. Louis Daily Levels, metres

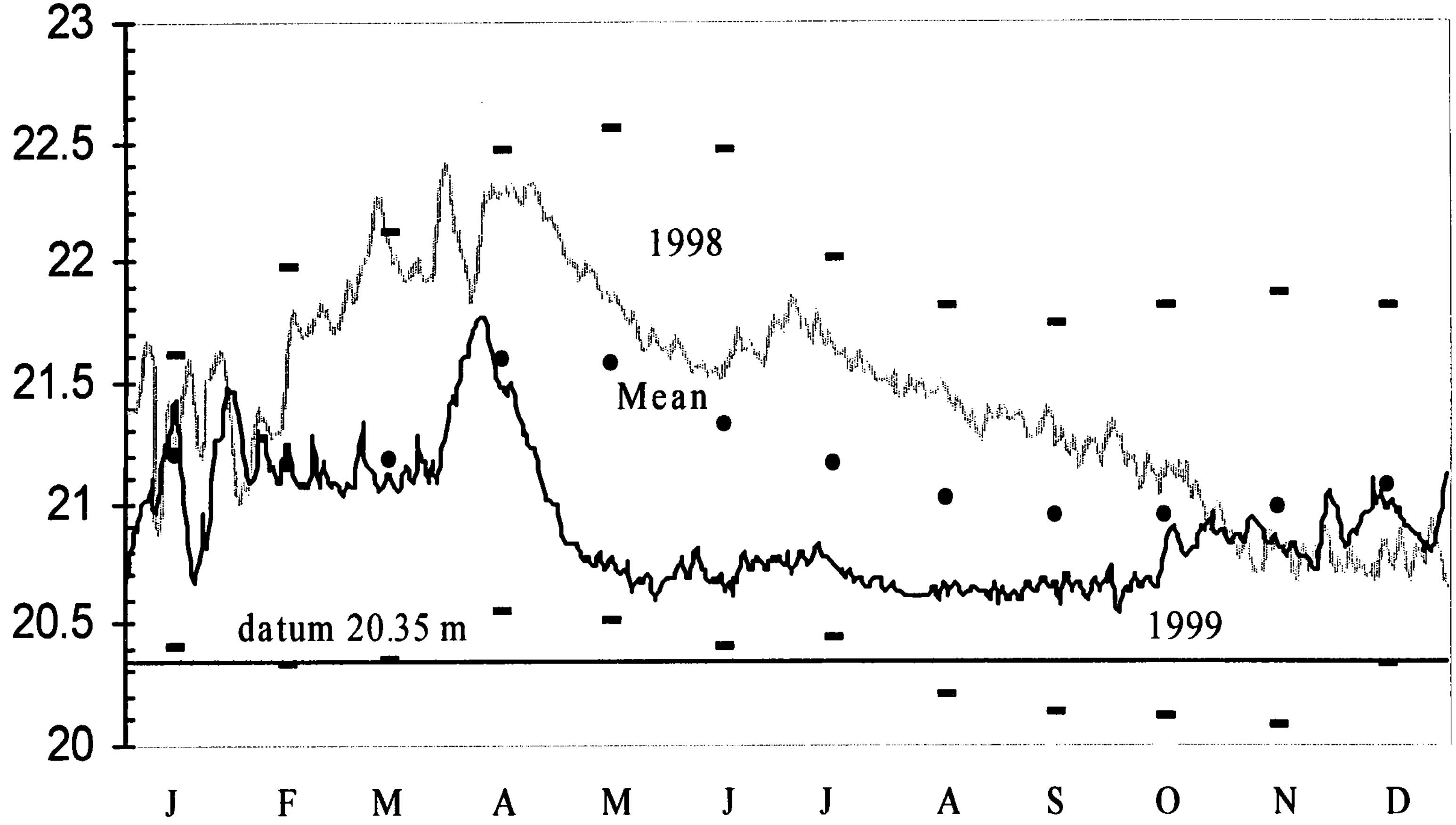


Figure 15 Montreal Harbour Daily Levels, metres