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TEMPORAL EFFECTS OF ST. CLAIR RIVER DREDGING ON LAKES ST. CLAIR AND ERIE WATER LEVELS AND CONNECTING CHANNEL FLOW[1]

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ABSTRACT. A Great Lakes hydrologic response model was used to study the temporal effects of St. Clair River dredging on Lakes St. Clair and Erie water levels and connecting channel flows. The dredging has had a significant effect on Great Lakes water levels since the mid-1980s. Uncompensated dredging permanently lowers the water levels of Lakes Michigan and Huron and causes a transitory rise in the water levels of Lakes St. Clair and Erie. Two hypothetical dredging projects, each equivalent to a 10 cm lowering of Lakes Michigan and Huron, were investigated. This lowering is approximately half the effect of the 7.6 and 8.2 meter dredging projects. In the first case the dredging was assumed to occur over a single year while in the second it was spread over a 2-year period. The dredging resulted in a maximum rise of 6 cm in the downstream levels of Lakes St. Clair and Erie. The corresponding increase in connecting channel flows was about 150 m^3s^{-1}. The effects were found to decrease over a 10-year period with a half-life of approximately 3 years. The maximum effects on Lake Erie lagged Lake St. Clair by about 1 year.
ADDITIONAL INDEX WORDS: Mathematical model, water quantity.

INTRODUCTION

The St. Clair River shown on Figure 1 connects Lake Huron with Lake St. Clair, serving as the outlet for the waters of the upper Great Lakes. The river is also the physical control for the levels of Lakes Michigan and Huron. St. Clair River channel dredging has had a significant impact on Great Lakes water levels since the mid-1800s. The first major dredging began about 1855 (Brunk 1968), and the latest project was completed in the early 1960s. In 1856 the depth of the improved channel was 4 meters; it is approximately 9 meters at the present time. This navigation dredging, along with sand and gravel mining, have reduced the levels of several of the lakes and have the potential for similar changes in the future. The primary impact has been to lower the levels of Lakes Michigan and Huron, along with smaller temporal impacts on Lakes St. Clair and Erie. Major uncompensated projects in this century include sand and gravel mining between 1908 and 1925 and the 7.6 m and 8.2 m navigation projects in the mid-1930s and late 1960s. The cumulative effect since 1900 has been a lowering of Lakes Michigan and Huron by 27 cm

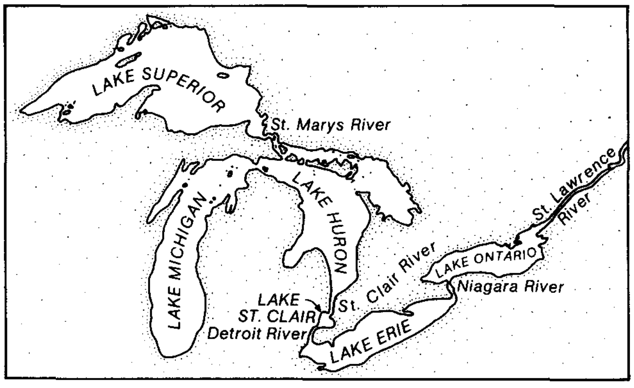

FIG. 1. Great Lakes location map.

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(Derecki 1985), which represents a permanent loss of 32 km^3 of fresh water. Accompanying the permanent drop in levels on Lakes Michigan and Huron were transitory increases in the water levels of Lakes St. Clair and Erie. Lake Superior has remained unaffected because of the current control works and, prior to that, the St. Marys Rapids. However, future projects could lower the levels of Lake Superior because the current regulation plan has a balancing component between the levels of Lakes Superior and Michigan-Huron. Since 1958, any impacts on Lake Ontario would have been mitigated by regulation.

While the permanent drop in levels has been well documented in the literature, the transitory impacts of dredging on downstream levels and flows, although significant, have not been addressed. This is primarily because the emphasis has been on determining the permanent effects of dredging using steady-state backwater analysis. This type of analysis gives the upstream effects but does not provide information on either downstream or temporal effects. In addition, until the development of mathematical response models such as Quinn (1978), such computations were time consuming and difficult.

In addition to being able to assess impacts of dredging on downstream interests, the analysis is also useful for time series studies of lake level data. Published lake level data from 1860 to date are available, constituting one of the longest series of continuously measured hydrologic data in North America. Because of the length of the series, the data lend themselves to time series analysis for examining lake level cycles and variations in water supplies, as well as correlations with sunspots, climatic variations, etc. Many users of the data have, however, failed to consider the anthropogenic changes in lake levels which may bias their analysis and which may lead to spurious correlations between lake levels and other data sets.

This study examines the magnitude and temporal effects of St. Clair River dredging on the levels of Lakes St. Clair and Erie and the connecting channel flows in the St. Clair, Detroit, and Niagara rivers.

PROCEDURE

Changes in lake levels due to dredging projects are well masked in the water level records because of seasonal and annual variations (Fig. 2). Mathematical routing models (Fig. 3) must therefore be used in the analysis. Figure 3 depicts the entire Great Lakes system including the regulation plans for Lake Superior, Plan 1977, and Lake Ontario, Plan 1958D. This study used the Great Lakes hydrologic response model (Quinn 1978), which incorporates the unregulated portion of the system from the St. Marys River to and including the Niagara River. The model is driven by monthly hydrometeorological data consisting of St. Marys River flows, overlake precipitation, basin runoff, lake evaporation, diversions, and connecting channel ice retardation

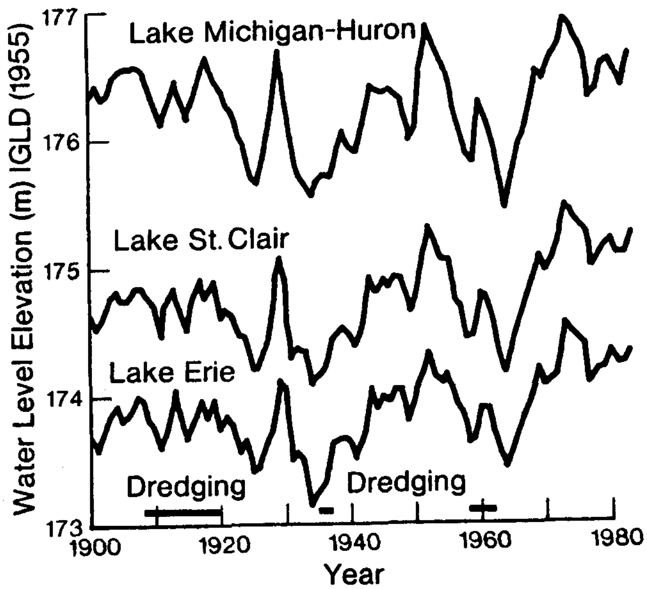

FIG. 2. Great Lakes annual water levels, 1900–82.

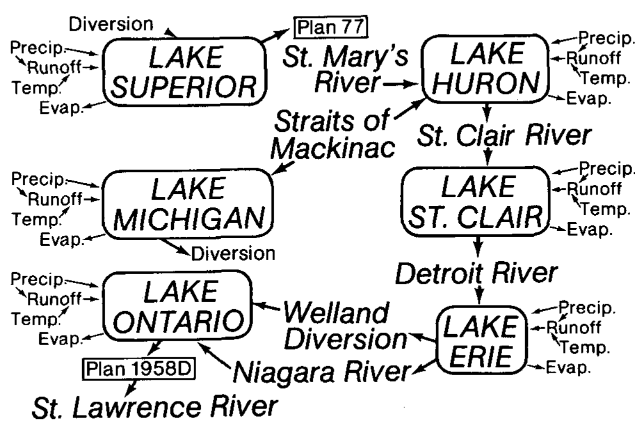

FIG. 3. Schematic of Great Lakes response model.

values for 1960–80 (Quinn and Kelley 1983). The model parameters for the connecting channels represent the present post-dredging channel regimes for the St. Clair, Detroit, and Niagara rivers. Model outputs consist of beginning-of-month and monthly mean water level elevations and monthly mean connecting channel flows.

A hypothetical project lowering Lake Michigan-Huron water levels by 10 cm was selected as a representative dredging project. This lowering is approximately half of the 18 cm lowering due to the combined dredging for the 7.6 and 8.2 meter navigation projects (IJC 1973). It can therefore be considered as typical of St. Clair River dredging projects. Lake levels and flows corresponding to the pre-dredging conditions were first simulated by adjusting the St. Clair River model parameters to raise Lake Michigan-Huron levels by 10 cm above the present conditions, while maintaining the same levels of Lakes St. Clair and Erie and the same flows in the St. Clair, Detroit, and Niagara rivers. The resulting levels and flows serve as the base conditions.

The response model was then run under two scenarios. In both cases, the dredging was assumed to occur from May through September, a normal period for dredging operations. The first scenario assumed that the dredging project occurred during a single year. In this case, the St. Clair River channel regime parameter was decreased from the adjusted value to the current value linearly over the 5-month dredging period. In the second scenario, the dredging was assumed to occur over a 2-year period. In each case, the Detroit and Niagara river regimes were held constant at the present conditions. The impact of dredging was determined by comparing the resulting levels and flows with those of the base conditions.

RESULTS

The simulated impacts of dredging on the level and flow regimes are illustrated in Figures 4 and 5. All comparisons are with the base conditions. Figure 4 shows the changes resulting from the single year dredging project. The flows of the St. Clair and Detroit rivers increase rapidly with the start of the project, reaching a maximum of 150 m^3s^{-1} at the completion of the dredging. The increases in the St. Clair and Detroit river flows are nearly identical because of the small storage capacity of Lake St. Clair. Lake St. Clair water levels also rise to a maximum value of 6 cm. The flow increase in the St. Clair River decreases rapidly to 100 m^3s^{-1} by the end of December. The reactions of the Niagara River flows and the Lake Erie levels lag because of the larger storage capacity of Lake Erie. The maximum increase in flow and lake level are 90 m^3s^{-1} and 5 cm, respectively, occurring midway through the second year. The impacts have a half-life of about 3 years and take approximately 10 years to dissipate completely. For perspective, the Chicago diversion of 91 m^3s^{-1} has permanently lowered Lake Erie by 4 cm (IJC 1976).

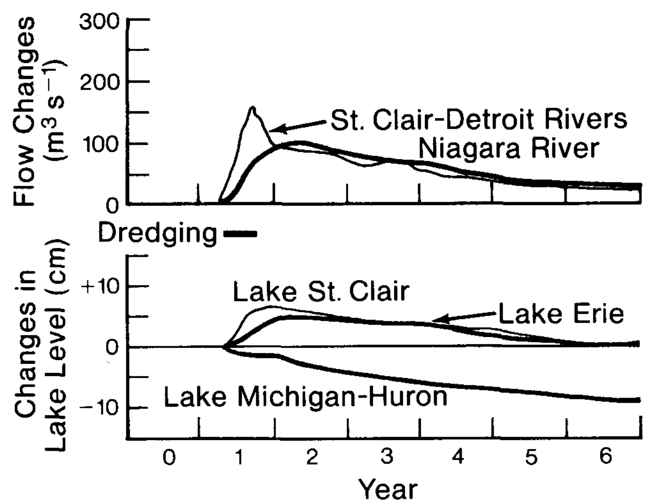

FIG. 4. Changes in flow in the St. Clair and Niagara rivers and in water levels in Lakes Michigan-Huron, St. Clair, and Erie as a result of single-year dredging in the St. Clair River.

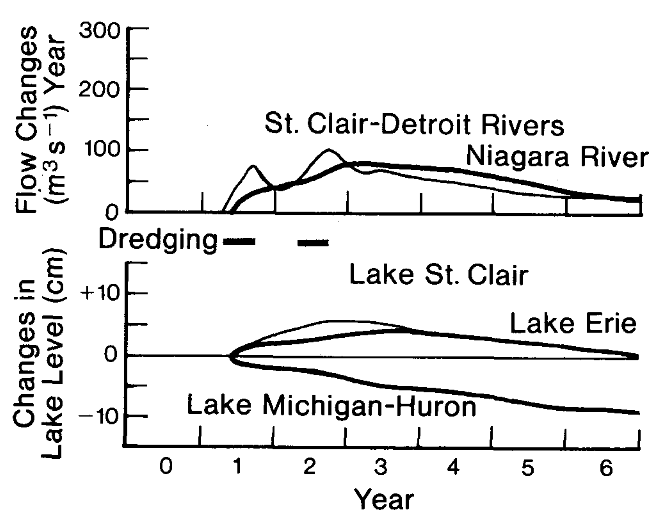

FIG. 5. Same as Figure 4 but as a result of 2-year dredging in the St. Clair River.

Figure 5 shows a double peak in the St. Clair and Detroit river flows, with maxima in the final month of dredging in each of the 2 years. The maximum flow increase of 110 m^3s^{-1} is reduced 27% from the single year dredging project. The maximum Niagara River flow increase of 85 m^3s^{-1} is a reduction of 15% from the corresponding single year dredging values. The maximum water level increases are 6 and 4 cm for Lake St. Clair and Lake Erie, respectively. The lake levels and flows from both projects returned to base conditions at approximately the same time.

CONCLUSIONS

Dredging projects in the St. Clair River have a significant, but temporary, effect on the levels of Lakes St. Clair and Erie and on the flows in the St. Clair, Detroit, and Niagara rivers. The peak impacts occurred near the end of the dredging project for the St. Clair and Detroit rivers and Lake St. Clair and lag about a year for Lake Erie and the Niagara River. The effects last for about 10 years, with a half-life of about 3 years. The maximum change in water levels due to the dredging are about 6 cm, approximately the same as for the Chicago Diversion. These effects should therefore be considered when conducting time series and correlation analysis using long-term Great Lakes water level data.

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