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HYDRAULIC INVESTIGATION FOR THE CONSTRUCTION OF ARTIFICIAL ISLANDS IN PEORIA LAKE

Illinois Department of Energy and Natural Resources

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HYDRAULIC INVESTIGATION FOR THE CONSTRUCTION OF ARTIFICIAL ISLANDS IN PEORIA LAKE

Final Report

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HYDRAULIC INVESTIGATION FOR THE CONSTRUCTION OF ARTIFICIAL ISLANDS IN PEORIA LAKE

by Misganaw Demissie, Ta Wei Soong, and Nani G. Bhowmik

INTRODUCTION

This report is based on a study conducted as a follow-up to the initial sediment investigation of Peoria Lake completed by the Illinois State Water Survey (ISWS) in 1985. The initial study demonstrated the seriousness of the sedimentation problem in Peoria Lake and quantified the sedimentation rates and the contribution of sediment from the major sources. In addition to quantification of the sedimentation problem, one of the major tasks of the initial study was to develop a list of alternative solutions, to evaluate those solutions on their technical merits, and then to make a recommendation as to the best sets of alternatives . to implement Two of the major components of the recommendation which resulted from the initial study were selective dredging and creation of artificial islands with the dredged sediment Selective dredging will make selected parts of the lake deeper and thus more accessible for recreation and will also provide improved habitat for fish and other aquatic organisms. However, one of the major problems of any dredging operation is finding the proper place to put the dredged material. In the case of Peoria Lake, considering the surface area of the lake and the amount of sediment in the lake, the most logical and probably the most economical means of disposing of the dredged sediment is to use it for building islands. If the islands are designed properly and placed at appropriate locations, they will enhance the environmental quality of the lake tremendously and thus will play a significant role in the rehabilitation and management of Peoria Lake. Thus both selective dredging and construction of islands can be performed together to improve and enhance the environmental quality of Peoria Lake.

However, before such a plan of selective dredging and creation of islands can be implemented, detailed hydraulic and engineering analyses and design are needed. It should also be pointed out that this is the first time this kind of project has been proposed for an environment like Peoria Lake, where a large river flows through the middle of a lake and the sediment in the lake is primarily silt and clay. This project was designed to conduct the initial hydraulic analyses on the feasibility of building islands from dredged material in Peoria Lake and to make recommendations on the type, size, number, and locations of the islands that would be needed for rehabilitation of the lake. This report summarizes the results of the project and makes recommendations to facilitate the construction of artificial islands from dredged material in Peoria Lake.

Acknowledgments

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Several staff members from the Illinois State Water Survey assisted in the project. Ranjie Xia, a graduate student in the Civil Engineering Department, assisted in the preparation of data and in modeling. Bill Bogner, Bill Fitzpatrick, Paul Makowski, and

Laura Keefer of the Surface Water Section, Richard Mark Twait of the Water Quality Section, and Frank Dillon and Jack Grubaugh of the Natural History Survey assisted in field data collection in Peoria Lake.

Amelia Greene and Cheri Chenoweth generated useful GIS maps for the project Illustrations were prepared by John Brother and Linda Riggin. Kathleen Brown prepared the draft and final copies of the report, and Gail Taylor edited it

BACKGROUND

Location

Peoria Lake is located in central Illinois on the Illinois River between River Miles (RM) 162 and 182 (figure 1). River miles on the Illinois River are distances measured from Grafton, Illinois, where the Illinois River meets the Mississippi River. The Illinois River is one of the major tributaries of the Upper Mississippi River (figure 2). The Illinois River forms a large part of the Illinois River Waterway, which is one of the major inland waterways in the United States. The Illinois Waterway makes navigation between the Great Lakes and the Mississippi River possible and serves as an important commercial transportation system for Illinois.

Problem

Peoria Lake is one of the most important water resources in central Illinois. It provides many benefits to the citizens of Illinois such as opportunities for recreation, fishing, and boating, and a channel for navigation. Most of the benefits of the lake have been taken for granted because the lake is a natural lake. However, the continuous accumulation of sediment over the years is threatening the existence of the lake. As of 1985, the lake had lost 68 percent of its 1903 volume due to sedimentation. The situation is even worse when the navigation channel, defined as that part of the lake which is 9 feet or deeper, is excluded from the lake volume calculations. Outside the navigation channel, Peoria Lake has lost 77 percent of its 1903 volume. The average depth of the whole lake (upper and lower) is only 2.6 feet, and the average depth of Upper Peoria Lake is only 2 feet

Peoria Lake has the highest sedimentation rate among all the large lakes and reservoirs in Illinois. This can be seen in table 1, which shows the sedimentation rates for the large lakes and reservoirs in Illinois, as determined from the lake capacity losses. The sedimentation rate for Peoria Lake is presented for two different periods because of the distinct difference in the rates for the periods from 1903 to 1965 and from 1965 to 1985. For the period from 1903 to 1965, the sedimentation rate for Peoria Lake was 0.63 percent per year, which is high but within the range of other sedimentation rates for large lakes and reservoirs in Illinois. The sedimentation rate for the period from 1965 to 1985 was 1.44 percent per year, which is more than double the rate for the previous period and by far the highest sedimentation rate among the large lakes and reservoirs in Illinois.

The severity of the sedimentation in Peoria Lake is illustrated by figure 3, in which the 1903 and 1985 lake bed profiles are compared at four locations along the lake. As can be inferred from this figure, much of the lake has filled up with sediment The sedimentation rate is higher in the upper lake than in the lower lake. The lake gets shallower in the upstream direction, and much of the upper end of the lake has filled up with sediment.

The net result of the sedimentation pattern in Peoria Lake is the shrinking of the deep parts of the lake. This is illustrated in figure 4, where the portions of the lake deeper than 5 feet are compared for 1903 and 1985. In 1903 much of the lake would have been deeper than 5 feet under present-day normal pool conditions, while in 1985 much of the lake was shallower than 5 feet with a narrow navigation channel in the middle of the lake. As sedimentation continues and the shallow flat areas start supporting vegetation, much of the lake will be transformed into a wetland area which will be flooded regularly. The transformation of Peoria Lake into a narrow navigation channel with bordering wetlands and mudflats will not only reduce aesthetic values but will also have negative impacts on recreation, real estate values, and tourism.

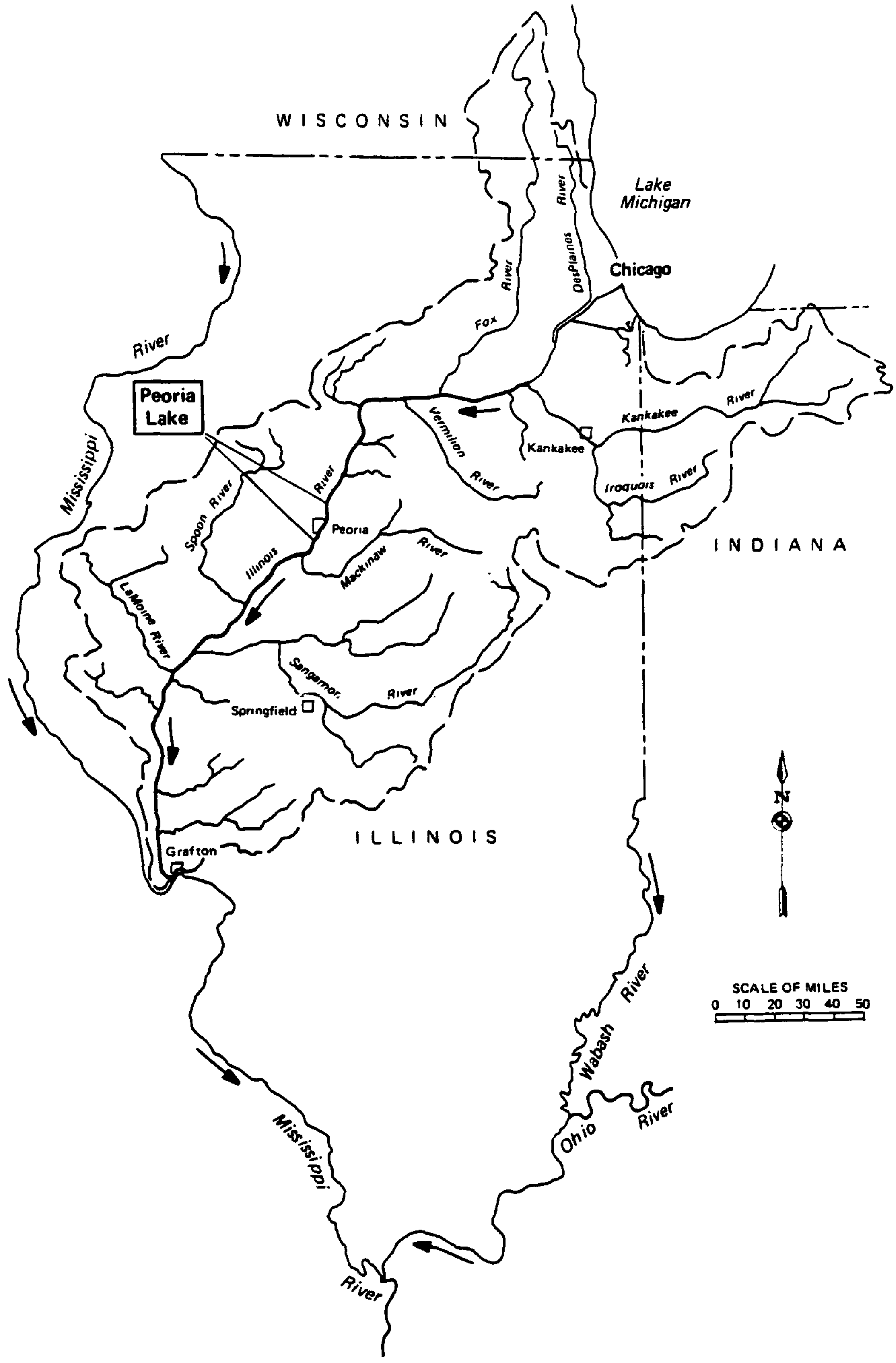

Figure 1. Location of Peoria Lake on the Illinois River

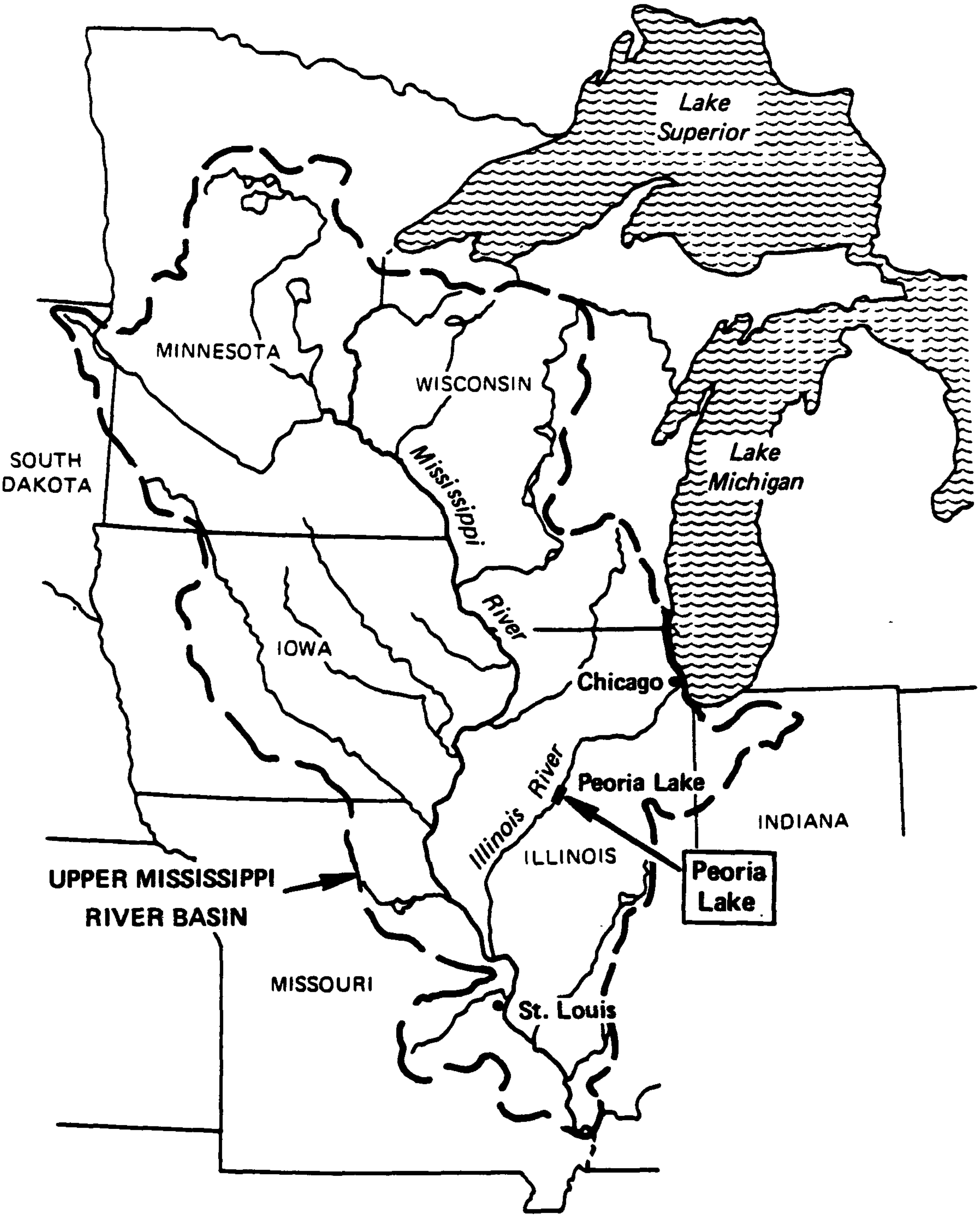

Figure 2. Location of the Illinois River within the Upper Mississippi River watershed

Table 1. Sedimentation Rates for Large Lakes and Reservoirs in Illinois

Reservoir	Initial volume (acre-feet)	Drainage area (sq mi)	Sedimentation period	Volume loss (percent/year)
Keokuk Pool	479,600	119,000	1913-1979	0.83
Lake Carlyle	280,600	2,680	1967-1976	0.53
Lake Shelbyville	207,800	1,054	1969-1980	0.37
Rend Lake	184,700	488	1970-1980	0.41
Peoria Lake	**120,000**	**14,165**	**1903-1965**	**0.63**
Peoria Lake	**120,000**	**14,165**	**1965-1985**	**1.44**
Crab Orchard Lake	70,700	196	1940-1951	0.44
Lake Springfield	59,900	265	1934-1984	0.26
Lake Decatur	27,900	925	1921-1983	0.53

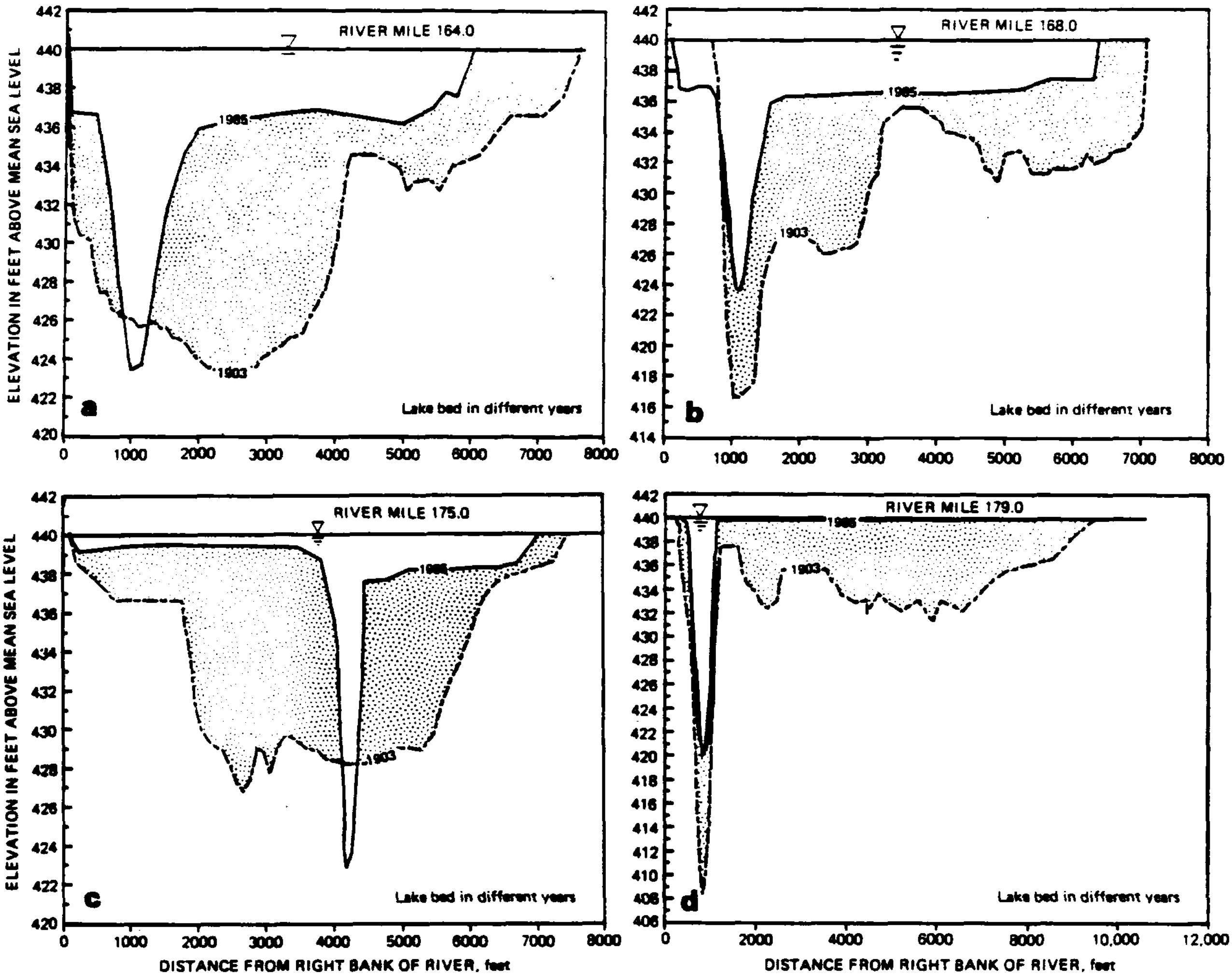

Figure 3. Comparison of 1903 and 1985 lake bed profiles for Peoria Lake

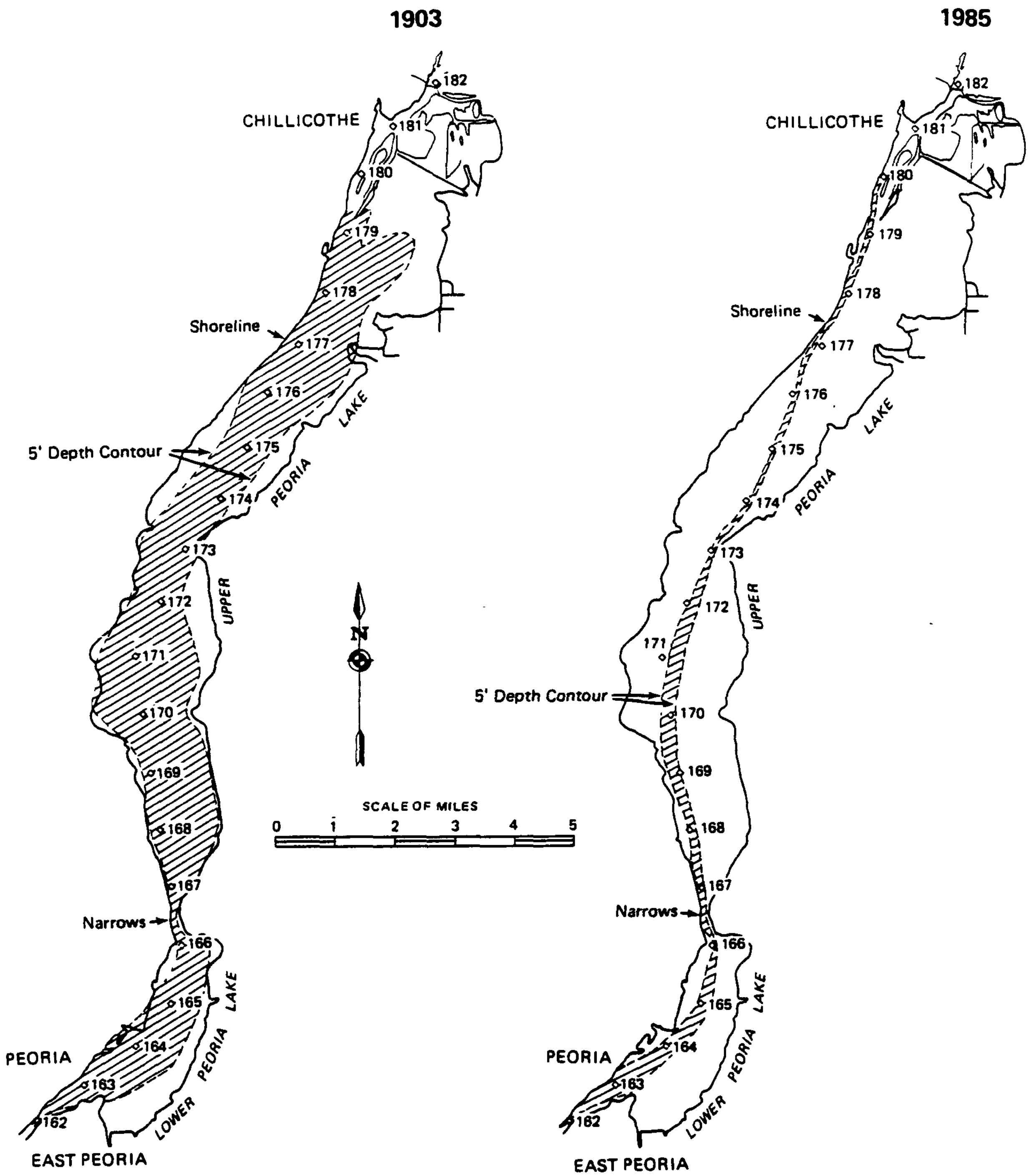

Figure 4. Lake area deeper than 5 feet in 1903 and 1985

Alternative Solutions

One of the main objectives of the 1985 Illinois State Water Survey study was to investigate a range of alternative solutions to the sedimentation problems and make recommendations as to the best alternatives. After information was gathered on a number of alternative solutions, the alternatives were grouped into the following four major categories, including the "do nothing" alternative.

1. Control sediment input into the lake
2. Manage the in-lake sediment
3. Hydraulically manipulate the Illinois River through Peoria Lake
4. Do nothing

Under each of the three major categories of alternatives (excluding the "do nothing" alternative), numerous alternatives were considered in the report of the study (Demissie and Bhowmik, 1985). For purposes of completeness and clarity, a complete list of the alternatives considered in the original report is presented below.

1. *Control sediment input*
   a. Control sediment input from tributary streams which drain directly to the lake.
   b. Implement best management practices (BMP's) on the Illinois River watershed to reduce erosion.
   c. Implement a shoreline protection program for Peoria Lake.
   d. Establish marshy areas to prevent bank erosion and resuspension of bottom sediment
   e. Construct a dam upstream of Peoria Lake to trap the sediment from the Illinois River.
   f. Provide upstream storage for high flows to reduce the sediment input into the lake.

2. *Manage in-lake sediment*
   a. Dredge selected areas of the lake.
   b. Lower the lake level to compact the sediment by drying.
   c. Lower the lake level for dry dredging.
   d. Dike part of the lake for dry dredging.
   e. Create artificial islands in the lake to form braided side channels, increase flow velocities, and reduce wave action.
   f. Experiment with thalweg disposal of dredged sediment

3. *Hydraulically manipulate the Illinois River through Peoria Lake*
   a. Raise the Peoria Dam.
   b. Build an in-lake dike (levee) to confine the Illinois River flow.
   c. Redirect the main flow of the Illinois River to the shallow parts of the lake.

d. Relocate the sailing line periodically.

e. Widen and deepen the Narrows.

f. Build a check dam at the Narrows.

After evaluating all of the above alternatives, Demissie and Bhowmik (1985) recommended a comprehensive lake management plan which would include all or some of the following alternatives:

- Selective dredging
- Creation of artificial islands
- Raising of the dam
- Creation of marshy areas
- Sediment input control

Among the components of the recommended comprehensive plan, the creation of artificial islands by selectively dredging certain areas has become one of the most promising alternatives to be carried out as part of a long-term solution.

The U.S. Army Corps of Engineers, Rock Island District, made an economic analysis of the construction of islands in Peoria Lake as a follow-up to the ISWS study. They assumed groups of islands in Lower and Upper Peoria Lake and estimated construction costs and recreational benefits. They did not include any other benefits (such as environmental enhancement) in their benefit calculations. With the above assumptions, they estimated that groups of islands in Lower and Upper Peoria Lake would have benefit/cost ratios of 4.3 and 5.0, respectively. On the basis of such high benefit/cost ratios, they concluded that the islands are economically justified. However, the Corps of Engineers could not pursue the project further because the project would not have flood control benefits. They recommended that the project be pursued by local and state groups (USACOE, 1987).

Although this alternative is quite promising, it requires more technical analysis and information than any of the other alternatives since this would be the first time such a project would have been attempted in an environment like Peoria Lake. This research project is the first attempt to investigate the technical aspects of constructing artificial islands in Peoria Lake.

ARTIFICIAL ISLANDS

Construction of artificial islands is not a new concept, even though this is the first time it is being proposed for lakes in the Illinois River valley. Artificial islands have been constructed in offshore areas as shore erosion control measures and as drilling platforms (Keith and Skjei, 1974; Garratt and Kry, 1978; Schnick et al., 1981). Numerous artificial islands also have been created by disposal of dredged material in coastal waterways, the Great Lakes, and the Upper Mississippi River (Soots and Landin, 1978; Schnick et al., 1981).

Artificial islands are also being constructed in Weaver Bottoms in Pool 5 of the Mississippi River (USACOE, 1986a,b). The artificial islands in Weaver Bottoms are part of a major habitat rehabilitation program by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service in the Upper Mississippi River. Weaver Bottoms is a 4,000-acre backwater lake which had problems associated with increased velocities, sedimentation, and turbidity (USACOE, 1986a,b). Artificial islands were selected as part of the project to reduce wind fetch and thus sediment resuspension and turbidity. Another benefit of the islands, in addition to improvement of the habitat, is that they serve as disposal sites for dredged material from maintenance of the 9-foot navigation channel in the Mississippi River.

Benefits of Artificial Islands in Peoria Lake

In Peoria Lake the construction of islands would serve many purposes. The main benefits would include the following:

1. **Providing improved and diversified aquatic, riparian, and terrestrial habitats.** The dredging of lake sediment at selected areas would create variable water depth habitats in areas which are presently very shallow. The dredged areas and the shoreline of the islands can be contoured so that they provide the desired water depth at selected locations during different water stages in the Illinois River. Such an arrangement should provide improved and diversified aquatic habitat for fish and other animals.

Because of the variable stages of the river, different parts of the islands would be inundated at different times. Some of these areas would behave like natural wetland areas and provide a different form of habitat that would enhance the aquatic habitat Further up at higher elevations on the islands mere would be areas which would not be inundated by water every year. These areas could be designed to provide riparian and terrestrial habitats to supplement the aquatic and wetland habitats. This should benefit both waterfowl and shore birds that are found in the Illinois River valley. In addition, the island habitat could provide a refuge to migratory and nesting birds.

2. **Serving as dredged material disposal sites for both navigation channel maintenance and selective dredging.** At present, frequent dredging is not required in the Peoria Lake area to maintain the navigation channel. However, that will not be the situation in the near future as the deeper portion of the lake keeps shrinking due to the continuous sedimentation in the lake. In some locations where the tributary deltas are very close to the navigation channel, as in the case of the Tenmile and Blue Creek Deltas, navigation channel dredging will be needed sooner than in other areas. Therefore, it would be to the long-term benefit of navigation interests to have sites to dispose of dredged material in Peoria Lake.

A large part of Peoria Lake needs to be dredged if it is going to provide deep water for fish and wildlife habitat and for recreation. If no dredging is performed, a large part of the lake will be transformed to mud flats and wetlands. However, dredging a large part of the lake would be expensive and will not likely happen. Therefore, with the limited financial resources available for lake rehabilitation, only selected areas could be dredged. If some selected areas are going to be dredged, then there is a need to find a disposal site for the dredged material. It is very unlikely that the necessary state and federal permits could be obtained for disposing of dredged material in the river channel and flushing it downstream, as is popularly believed. Thus islands would be an advantageous addition to the proposals for dredging in Peoria Lake.

3. **Reducing wind- and navigation-induced resuspension of sediment and turbidity.** One of the major environmental problems in Peoria Lake is the resuspension of fine sediment due to wind- and navigation-induced waves. The problem is aggravated by the shallowness of a large part of the lake and the fine unconsolidated sediment at the bottom of - the lake. Peoria Lake is over a mile to as much as two miles wide (west to east) at many places. Lower Peoria Lake is about 4 miles long, and Upper Peoria Lake is over 14 miles long in a south-to-north orientation. These dimensions and the prevailing wind direction in the area, which is southwesterly, provide long fetches for wind to generate waves sufficient to resuspend the sediment in the lake frequently. Navigation and recreational boating also generate significant waves that resuspend sediment in the lake. Therefore the construction of islands that reduce the fetch of the wind would reduce the generation of waves in the protected areas and the resuspension of bottom sediment into the water column. At the same time, constructing islands between the navigation channel and some parts of the lake would shelter the area on the opposite side of the navigation channel from waves generated by tows and pleasure crafts. This would reduce the negative impacts of navigation and recreational boating in some areas of the lake.

4. **Reducing sedimentation rates in the areas where islands are constructed.** Constructing islands in Peoria Lake should create slighdy reduced flow areas, thus increasing the flow velocity through the area. In Peoria Lake, the flow areas are so large that the velocities under existing conditions are very small, resulting in high sedimentation rates. Increasing the flow velocity would reduce the sedimentation rate in the areas where the islands are built

5. **Providing more suitable water-based recreational sites in Peoria Lake.** At the present time only a small part of the lake is used for recreation. These areas are limited to Lower Peoria Lake and the lower part of Upper Peoria Lake. The availability of suitable recreational areas will continuously diminish as the lake fills up with sediment At the same time the need for water-based recreation is expected to increase. Selective dredging and island construction would provide some relief to the shrinking recreational areas in the lake by increasing areas for water-based activities such as boating, sailing, and water skiing.

6. **Providing a side channel away from the navigation channel for safe recreational boating.** One of the concepts developed in this project is the inclusion of a side channel along the islands on the opposite side from the navigation channel. The side channel, in addition to providing an improved aquatic habitat to tiiat provided by the shallow channel border areas, would provide a safe recreational boating and sailing channel away from the navigation channel and its large commercial navigation crafts.

Conceptual Considerations

The concept of constructing artificial islands in Peoria Lake has been developed as part of a comprehensive lake management program. After exhaustive analysis of the different alternatives available to rehabilitate Peoria Lake, selective dredging and creation of artificial islands with the dredged material appear to be the most promising alternatives to deal with the sediment already in the lake. Indiscriminate dredging of the whole or even just part of the lake is not feasible for many reasons. The major reason is the cost of dredging and, most importantly, the cost of disposing of the sediment Therefore, a sound alternative will include dredging selected areas of the lake and using the dredge material to construct islands which will improve the aquatic and terrestrial habitat in the lake.

The selection of the dredge sites and the location of islands is an important consideration in implementing a long-term lake rehabilitation and management program. The dredge sites and the islands have to be located such that the new environment created can be integrated into the river and lake environment and sustained for a long period of time. The best method for achieving such an environment in Peoria Lake is to establish a side channel by dredging and use the dredged material to partially build the islands, as shown in figure 5. If properly designed and constructed, this arrangement of islands and side channels should maintain and sustain itself and blend in with the natural environment very well. In fact, the presence of a side channel and an island or groups of islands is a common feature in the Illinois River valley in areas where the river does not flow in constricted reaches. Therefore, the selection of island and side channel locations in Peoria Lake should be based on establishing an environment that functions and looks like a natural environment and that improves the overall quality of the lake for fish and wildlife habitat and for recreation.

Locations of Islands and Side Channels

After careful study of the flow pattern in Peoria Lake (taking into consideration other factors such as wind direction and availability of sand and gravel), two areas in the lake were selected as the best locations for constructing islands and side channels that will integrate well with the lake environment One of the locations is in Lower Peoria Lake, and the other is in the lower part of Upper Peoria Lake, sometimes referred to as Middle Peoria Lake. These two locations are shown in figure 6. They were selected on the basis of considerations relating to the following conditions:

1. Existing **flow pattern and expected flow tendencies.** Since the addition of a side channel along with the island will enhance the environment much more than an isolated island in the middle of the lake, it is important that the island and side channel be situated so that a certain amount of flow can be maintained in the side channel.

2. **Wind direction.** The predominant wind direction in the Peoria area is southwesterly. Therefore the islands should be located so that they can reduce the fetch for southwesterly winds.

3. **Anticipated sedimentation rates.** The islands and side channels should not be built where the sedimentation rate in the side channel is expected to be high. The side channels should be located so that they can sustain themselves for a long time without requiring frequent dredging.

4. **Availability of sand and gravel not too far from the island locations.** It is anticipated that a sand dike will be required to build the islands. The distance of the island sites from a source of sand and gravel will affect the cost of building the islands. Therefore to minimize the cost, it would be a good idea to locate the islands close to a source of sand and gravel.

At other locations, primarily in Upper Peoria Lake, some of the necessary requirements are not met and it would be very difficult to maintain flow and channel depth at design levels. For other locations which do not meet the requirements, other management alternatives need to be developed based on flow characteristics and expected sedimentation rates.

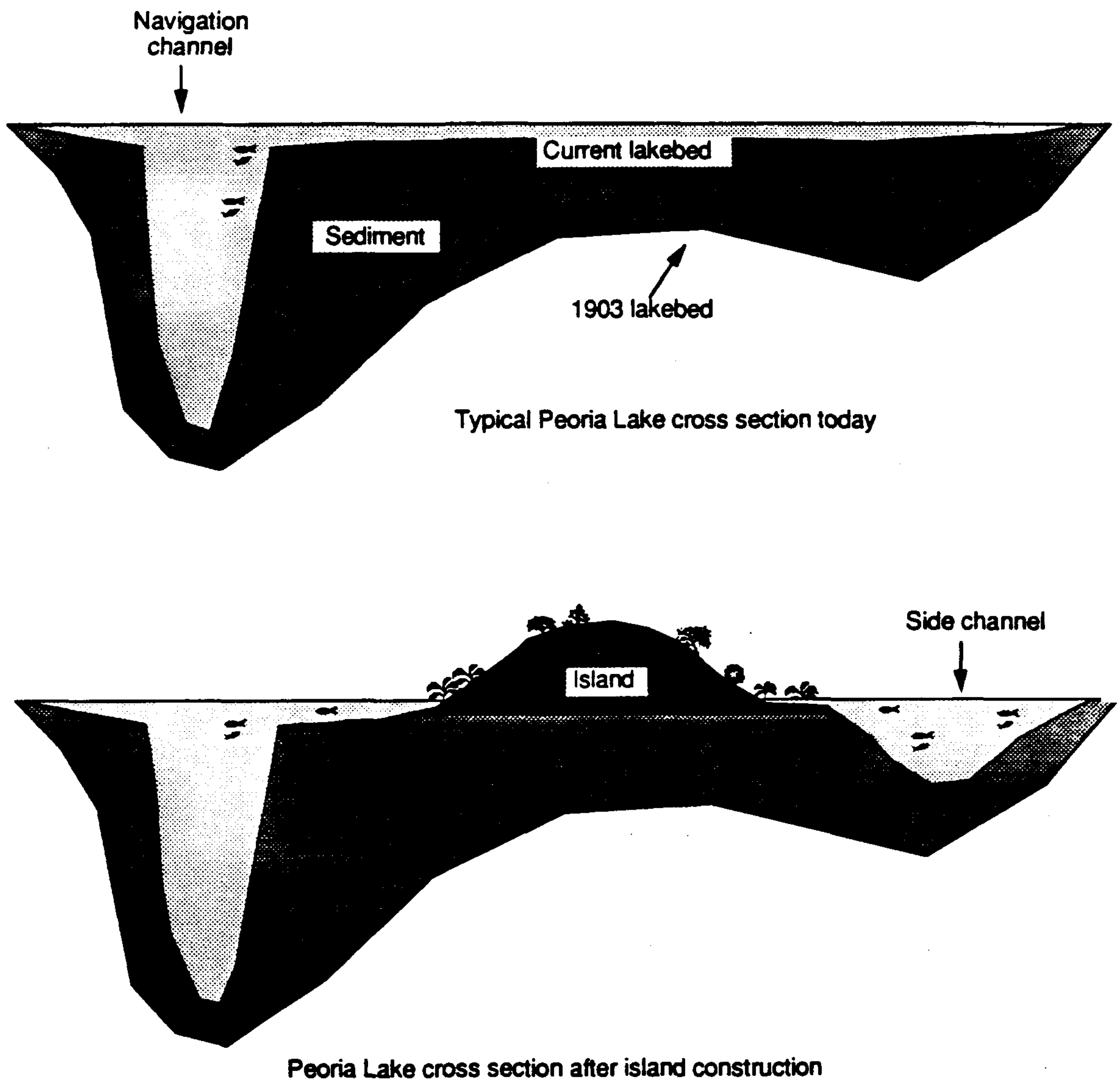

Figure 5. Artificial island concept for Peoria Lake

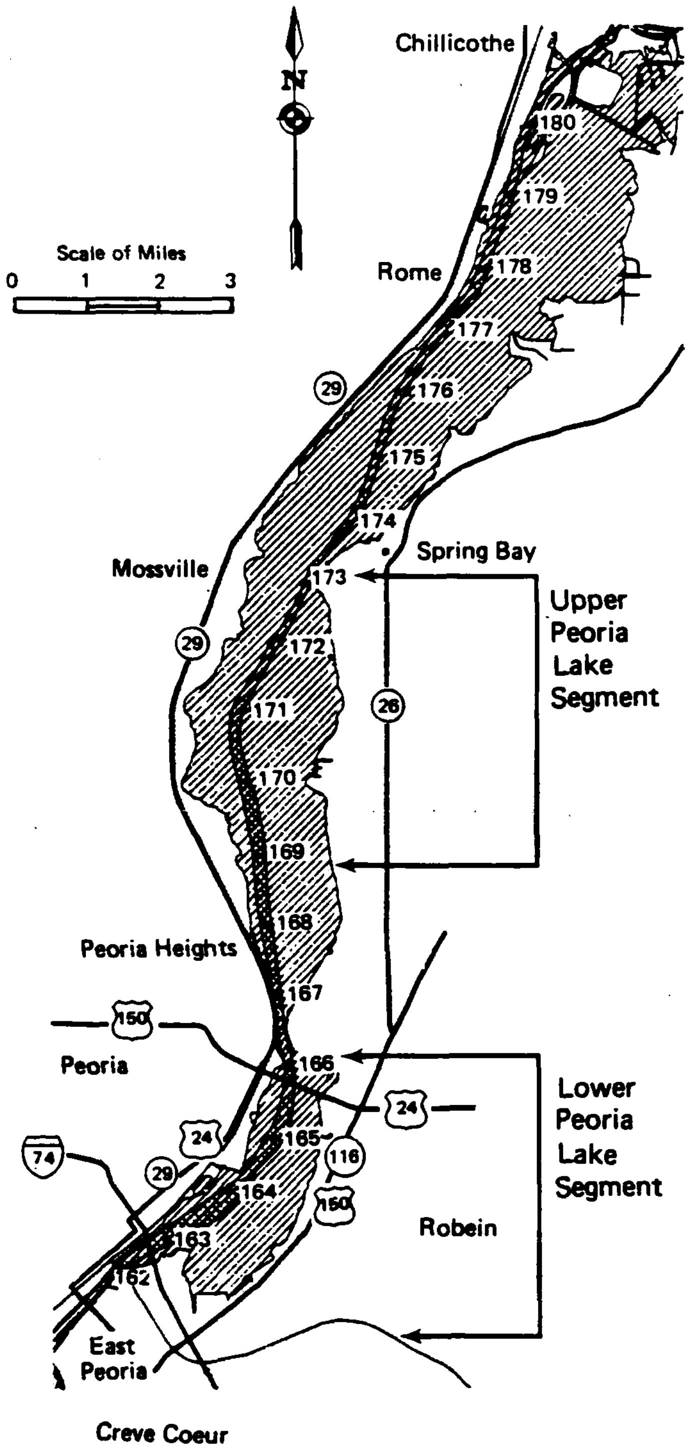

Figure 6. Two areas found to be the best locations for building islands in Peoria Lake

Size, Shape, and Number of Islands

A discussion of the size and number of islands has to consider several phases. In the most immediate and most important phase, the size and number of islands that can be built is limited by the amount of money that is likely to be available from federal and state sources. From the technical point of view also, there is a need to construct one island as a demonstration project to learn the problems and advantages of dredging and building islands in an environment like Peoria Lake. Further dredging and construction of islands will then depend on the experience with the demonstration project.

Another perspective would be to look at the long-term needs for comprehensive lake management for Peoria Lake. With that perspective in mind, several options were investigated. These include building from two to four islands in both Lower and Upper Peoria Lake. Such arrangements are shown in figures 7 and 8 for Lower and Upper Peoria Lake, respectively. The dredging required to build these islands should create sufficient deep-water areas for both habitat enhancement and recreation. The amount of dredging will of course depend on the size of each island. In this study, island sizes ranging from 14 acres to 143 acres were investigated. The size of the first proposed island, depending on how much funding is requested, is 25 to 30 acres. Such an island might occupy a volume of somewhat over 500 acre-feet, depending upon its height Thus the dredging requirements might exceed 1000 acre-feet, which is twice as much as the island volume. This is because of the dewatering and compaction of lake sediment as it is used for building islands.

The shape of the islands depends on many factors other than hydraulics. On the basis of the hydraulics of flow and sedimentation patterns, simple oval-shaped islands will be sufficient and consistent with other islands found in the Illinois River valley. However, habitat enhancement considerations might require different shapes which maximize the shoreline of the islands. This requirement can be satisfied by varying the contours of the islands near the water surface, while keeping the basic oval shapes of the islands from the bottom to near the water surface.

Dredging and Construction Considerations

In this section general considerations in the dredging and construction of the islands are discussed. Detailed and specific information and discussions cannot be provided because the specific site and exact size of the island (or islands) have not been determined. The general discussions included here will be applicable to all the proposed sites.

The concept of island construction in Peoria Lake has to be understood correctly in its entirety. Islands by themselves are not going to solve the sedimentation problem or significantly improve the habitat in the lake. The important factor is the way the islands and the dredging which must accompany the island building are integrated into the whole river and lake environment To build an island which occupies 1 acre-foot of space, at least 2 acre-feet of sediment in the lake must be dredged. This ratio of island volume to dredging volume of roughly 1:2 is due to dewatering and consolidation of the lake sediment as it is used to build the islands. Therefore, island building in Peoria Lake would require a significant amount of dredging, which would increase the area of the lake that is deeper than 3 feet and significantly improve the aquatic habitat and recreation potential. Thus it is not only the location and size of the islands that are important; equally as important are the location and amount of dredging in the lake.

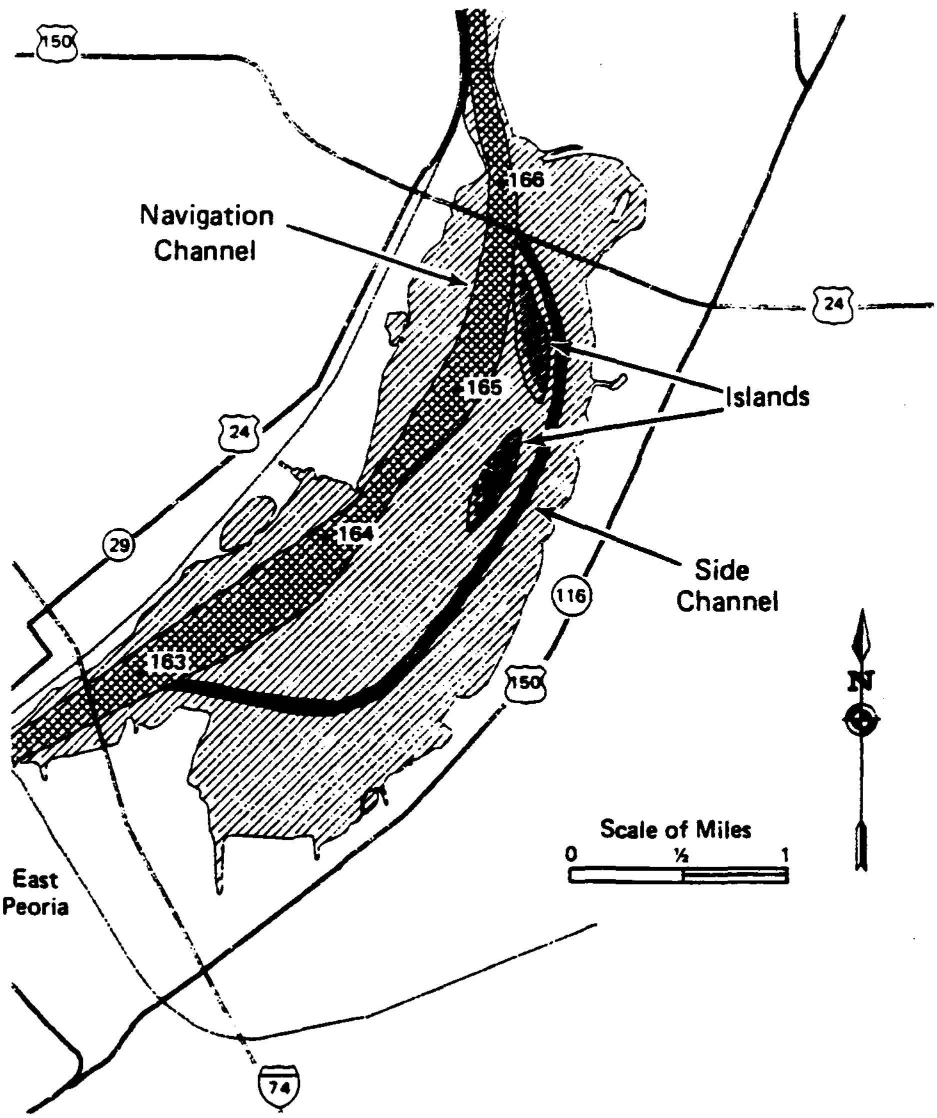

Figure 7. Possible locations of two islands and a side channel in Lower Peoria Lake

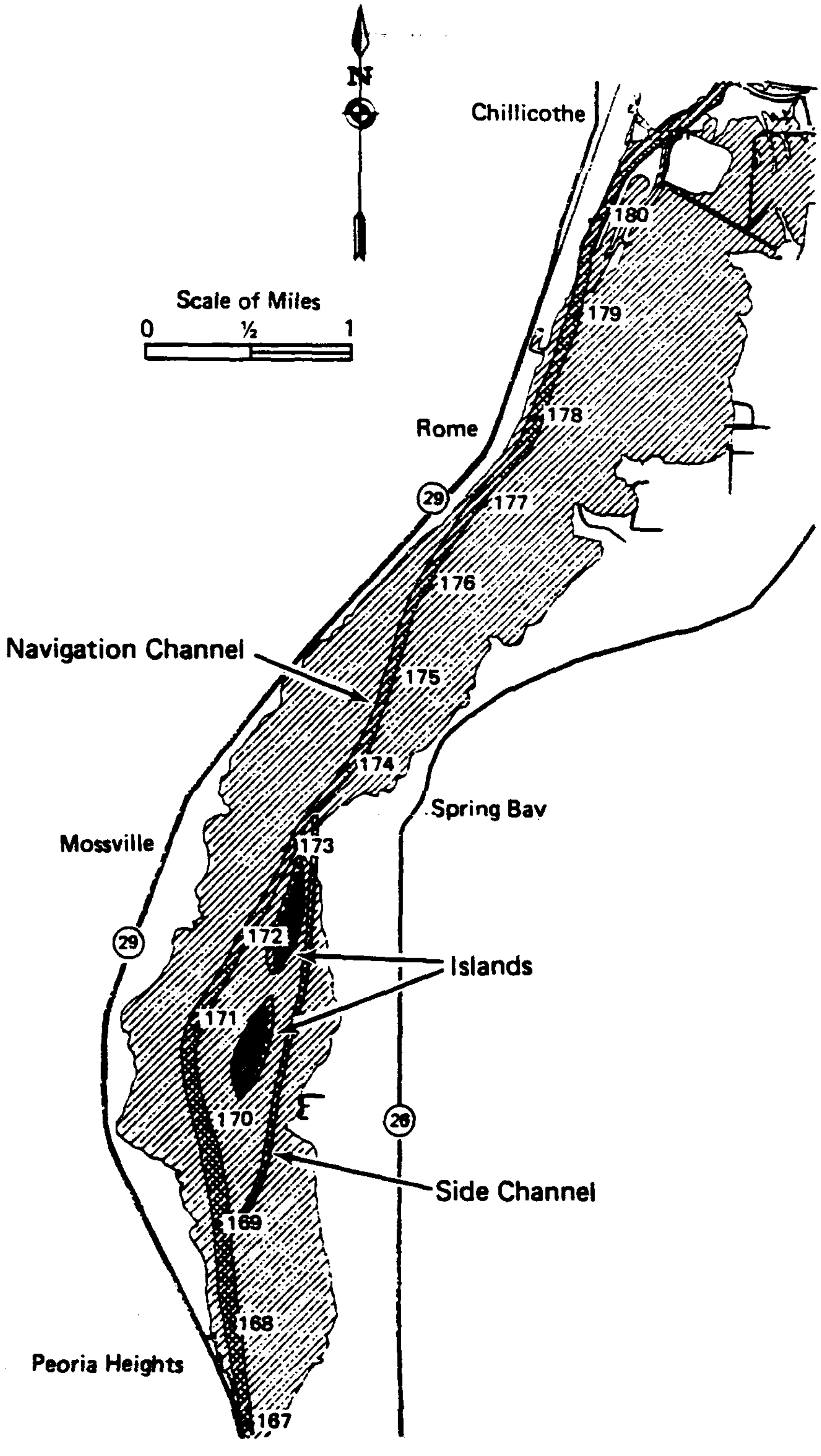

Figure 8. Possible locations of two islands and a side channel in Upper Peoria Lake

Another major consideration is the process of island construction. When the sediment is sand and gravel, it is possible to construct islands by dredging the sediment and piling it on specified areas. This type of operation was common in the Mississippi River, where islands were created by dredging the navigation channel and discharging the coarse sediment to the side. The characteristics of the sediment in the Illinois River valley are drastically different from those of the sediment in the Mississippi River. A large percentage of the sediment in Peoria Lake is silt and clay; therefore it would be almost impossible to construct an island by simply dredging and disposing of the sediment at the site. A retaining dike system would be needed to hold the dredged sediment and let it settle down to the bottom and consolidate, as shown in figure 9. This type of operation is common when contaminated sediment is disposed of in an aquatic environment (USACOE, undated; Rotterdam Public Works, 1986). A dike is initially built around the disposal site, and the contaminated sediment is pumped into the diked area. The contaminated sediment settles to the bottom and remains there without having the potential to contaminate other areas or fish and other organisms.

In Peoria Lake, the use of dikes built of sand to hold the fine sediment until it settles and consolidates appears to be the best construction mediod. This is not because the sediment is highly contaminated with toxic chemicals, but because the sediment is very fine and thus will require a retaining structure to contain it

If the dike system is finally selected as the mediod to use in building the islands, then the next question is the availability of enough sand and gravel to build the dike system. One of the unique features of Peoria Lake is the presence of several tributary deltas on the eastern shore of the lake. The major ones include the Farm Creek Delta in Lower Peoria Lake, the Tenmile Creek Delta at the Narrows, and the Blue Creek and Richland Creek Deltas in Upper Peoria Lake. Even though detailed analysis has not been performed, most of the material making up the deltas consists of sand and gravel. Therefore, depending on where the islands are built, mere should be sufficient sand and gravel available to build die required dikes. The proximity of potential locations to one of the major deltas was in fact one of the criteria in selecting sites for the islands.

Another alternative to the dike system is the possibility of using used barges around the perimeter of the island. This possibility, of course, depends on the availability of a sufficient number of old barges and the cost of the whole operation. If the dike system gets to be expensive, the use of barges instead of sand dikes might be the best alternative.

Further construction-related questions pertain to the means and the time required to drain water from the dredged material. These questions will be answered as detailed designs and procedures are prepared after the exact location and size of the island are selected.

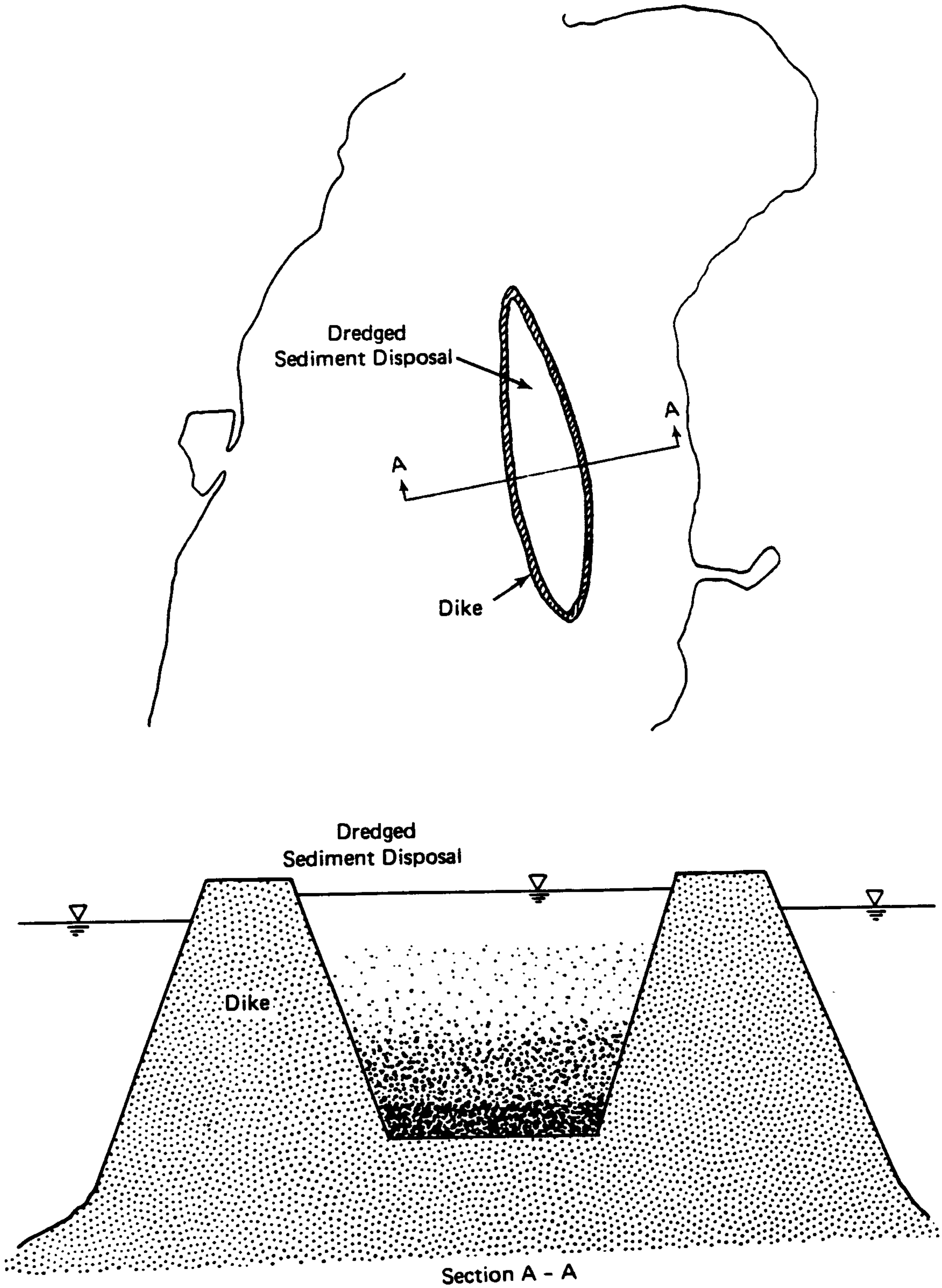

Figure 9. Diked island construction concept

HYDRAULIC ANALYSES

General Hydraulic Analyses

Before detailed mathematical modeling was performed, general hydraulic analyses were conducted to answer some basic questions related to flow pattern and sediment movement in the lake. These included questions regarding flow and sedimentation pattern in the lake, and general island shape, size, and possible locations.

Initially, the hydraulics of Peoria Lake has to be discussed within the context of the Illinois River and the Illinois River Waterway (figure 10). The Illinois River has to be looked at in terms of two distinctly different segments: the upper Illinois River and the lower Illinois River. In its upper reaches, from the junction of the Des Plaines and Kankakee Rivers to the Starved Rock Lock and Dam, the Illinois River is a steep-gradient river with an average slope of 1.2 feet per mile. The lower Illinois River, from the Starved Rock Lock and Dam to the junction of the Illinois River and the Mississippi River at Grafton, is a very gentle-gradient river with an average slope of only 0.17 foot per mile. This significant difference in gradient of the river has resulted in different flow regimes and sediment transport capabilities in the two segments of the river. Under natural conditions, flow velocities generally correspond to the gradient of the river and are therefore significandy higher in the upper reaches than in the lower reaches of me river. The lower river is thus a natural sediment trap, while me upper portions have not had much of a sedimentation problem.

Presendy, the hydraulics of the Illinois River is controlled by six locks and dams during 16w and medium flows (figure 10). Five of the lock and dam structures are on the Illinois River, and the sixth is on the Mississippi River and controls the lower 80 miles of the Illinois River. With the Brandon Road Lock and Dam on the Des Plaines River and the Lockport Lock and Dam on the Chicago Sanitary and Ship Canal, the Illinois River forms the Illinois Waterway, which connects the Great Lakes with the Mississippi River and ultimately with the Gulf of Mexico at New Orleans.

During periods of high flow in the Illinois River, the dams at Peoria and LaGrange on the lower Illinois River are lowered to the channel bottom, allowing the lower portion of the river in the Peoria and LaGrange Pools to become a free-flowing river. The only control downstream of the LaGrange Lock and Dam is Lock and Dam 26 on the Mississippi River near Alton, Illinois. Even though Lock and Dam 26 controls the lower 80 miles. of the Illinois River, its operation is determined on the basis of flow conditions in the Mississippi River. Peoria Pool is located at the upper end of the lower river, where the gradient and velocities change from relatively high to low. In most areas of the pool, with the exception of narrow and constricted sections, flow velocities are small as shown in figure 11. The decrease in velocity in the lower Illinois River results in higher sedimentation rates than in the upper reaches of the Illinois River. Peoria Lake is over a mile wide in most places and thus provides a large flow area. which results in very small velocities.

Through the process of the navigation channel development and the distribution of sediment in the lake, a distinct channel morphology has developed in Peoria Lake. There is now a deep channel in the middle of the lake, and outside tins deep channel is a vast shallow lake area. Figure 12 shows a cross section in Lower Peoria Lake during a relatively high flow of 50,000 cfs. The velocity distribution across the lake corresponds very well with the depth of water, as shown by comparing figures 12 and 13. Velocities outside the navigation channel rarely exceed 1 foot per second. This low velocity along much of the lake area results in high sedimentation rates for the lake.

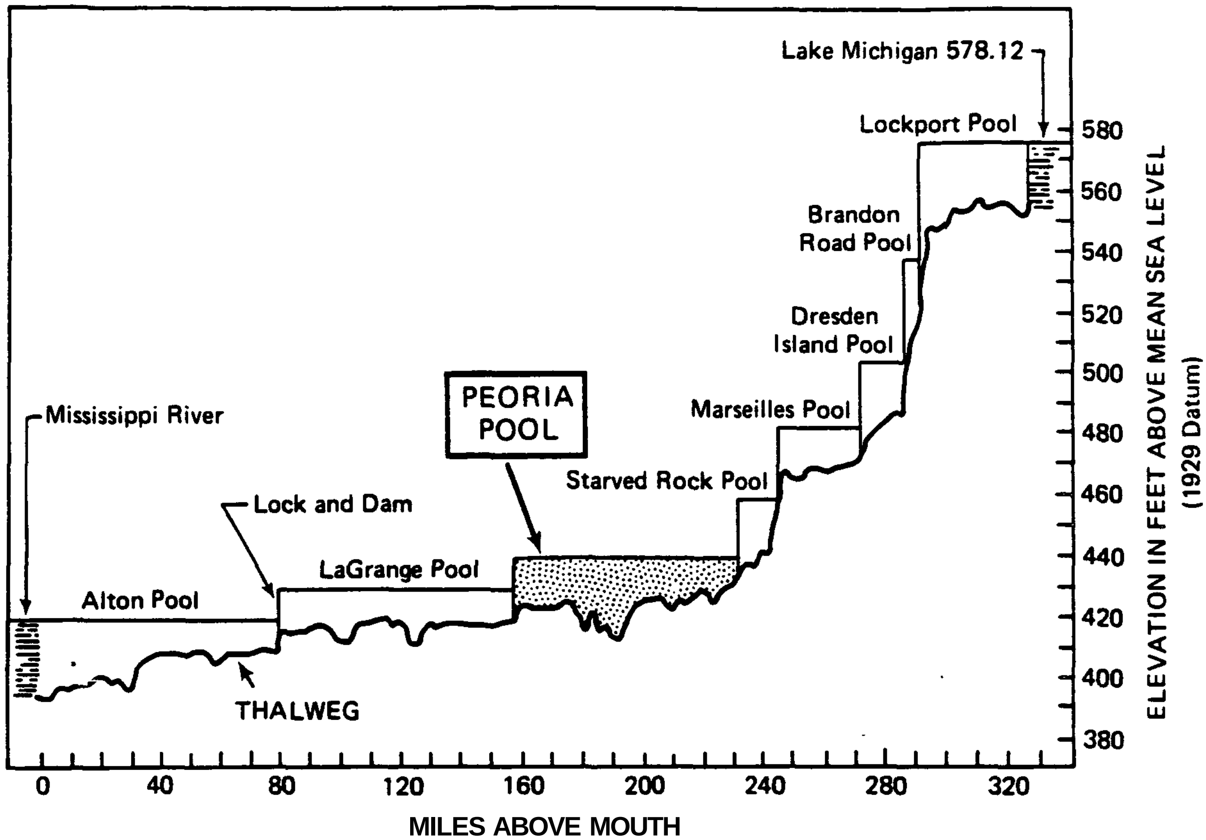

Figure 10. Profile of Illinois River Waterway

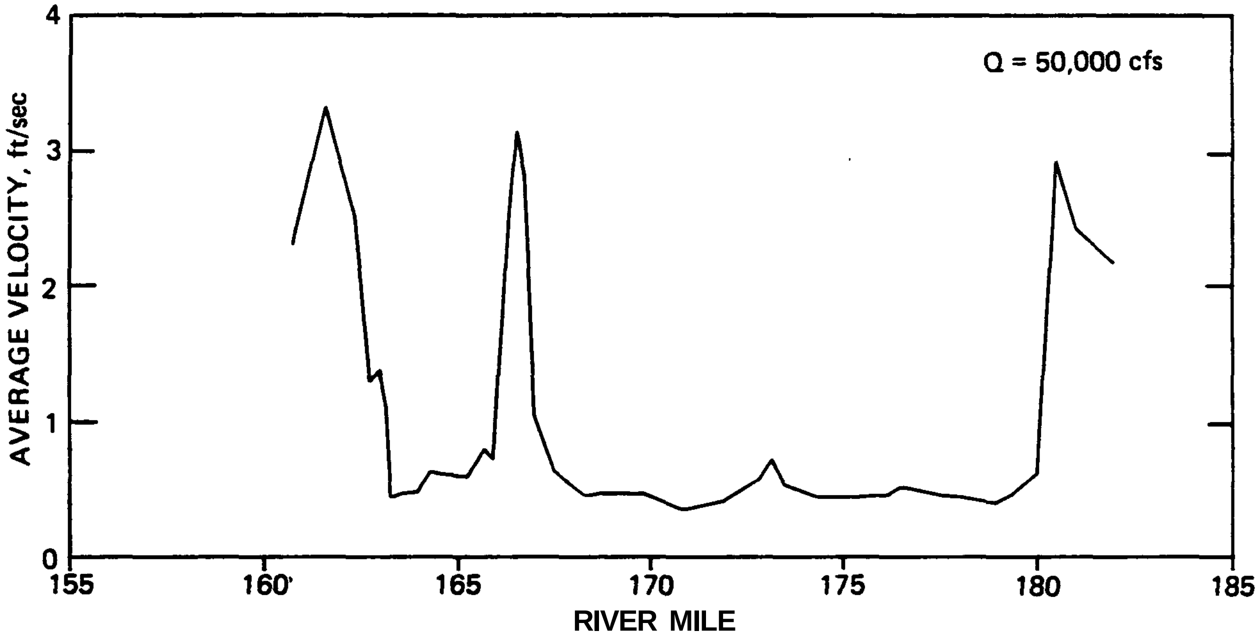

Figure 11. Average velocities in Peoria Lake for Q = 50,000 cfs

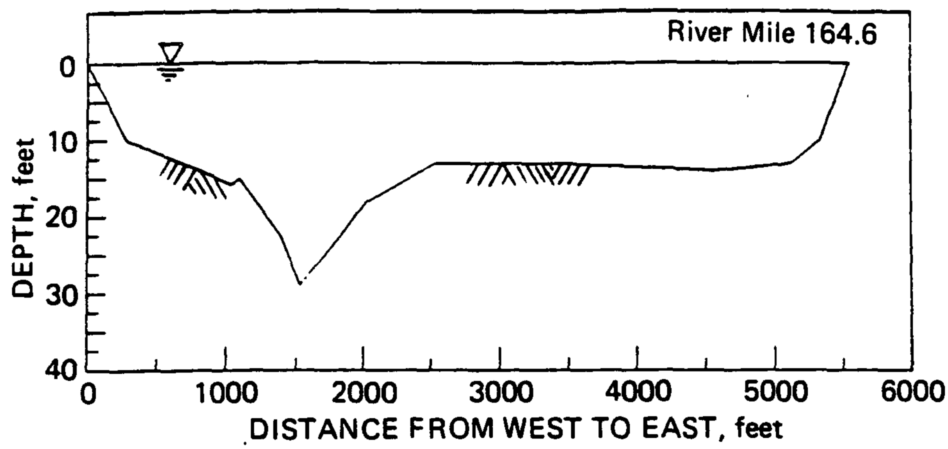

Figure 12. Typical cross-sectional profile in Peoria Lake

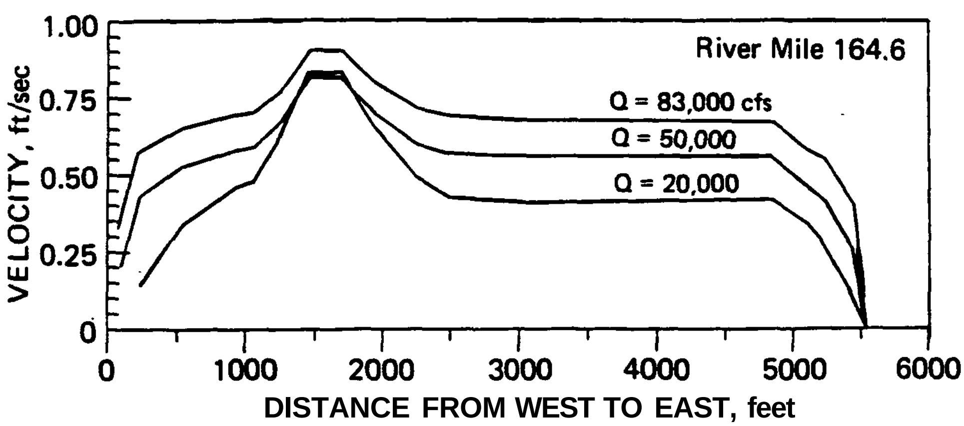

Figure 13. Typical velocity distribution across Peoria Lake

Mathematical Modeling

Two mathematical models were used to investigate the impacts on hydraulics and sediment transport which may result from island construction in Peoria Lake. The two models are known as the HEC-6 and TABS-2 models. The HEC-6 model, developed by the U.S. Army Hydrologic Engineering Center, is a one-dimensional sediment transport model for rivers and reservoirs (USACOE, 1977). TABS-2, developed by the U.S. Army Waterway Experimental Station, is a large model consisting of three major components (modules). These modules deal with hydrodynamics, sediment transport, and transport of dissolved and neutrally buoyant substances and are programmed in two-dimensional finite element codes (Thomas and McAnally, 1985).

Two-dimensional models differ from one-dimensional models in many ways. In general, the equations used are more complex and the cost to run the models is higher for two-dimensional models than for one-dimensional models. The major difference between the two types of models is the detail of the results obtained from the models. One-dimensional models provide information in only one direction, while two-dimensional models provide information in two directions. In this study the HEC-6 was used to investigate the responses of the whole lake from Chillicothe to the Franklin Street bridge, while TABS-2 was applied to the segments of the lake where it is assumed that islands would be built and for which detailed hydraulic information is sought Descriptions of these two mathematical models are given in the following sections.

HEC-6 Model

Model Description

The HEC-6 model is a one-dimensional simulation program designed to analyze scour and deposition of sediment in rivers and reservoirs (USACOE, 1977). It simulates the ability of the stream to transport sediment and encompasses the full range of conditions embodied in Einstein's Bed Load Function, plus the transport and deposition of silt and clay, armoring, and the destruction of the armor layer in a stream channel. The sediment transport capacity is calculated by using the models given by Laursen (1958) or Toffaleti (1966). However, any other sediment transport equation can be specified by the user.

The basic equation used in the model is the continuity-of-sediment-material equation:

$$\frac{\partial G}{\partial x} + B\frac{\partial y_s}{\partial t} = 0 \qquad (1)$$

where

B = width of deposit or scour area (movable bed)
G = sediment load
ys = depth of sediment deposit or scour above a stable layer
t = time
x = distance along the channel

The HEC-6 model uses an implicit finite difference scheme to numerically solve equation 1 and the sediment transport equation. Initially, the water surface profile and all the pertinent hydraulic parameters (elevation, slope, velocity, depth, and width) at each cross section along the study reach are computed in a fashion similar to that in the HEC-2 Water

Surface Profile Computer Program (USACOE, 1979). This information is then used to calculate the inflow sediment load, armoring, equilibrium depth, gradation of material in the active layer, and transport capacity for each reach between two cross sections. The transport capacity is determined analytically from empirical relations incorporated in the model.

The program finally calculates the sediment load leaving the study reach and the change in the volume of bed material to reflect scour or deposition. The depth of deposit or scour is adjusted to reflect the new volume. The above procedure is repeated for a sequence of water discharges (derived from the discretized hydrograph) and the corresponding sediment loads. The changes are calculated with respect to time for each reach within the study area.

Despite the advanced features HEC-6 has for simulating sediment transport, it is only a one-dimensional model and the results are averages for the whole reach of a river or reservoir. In order to provide more detailed information, the HEC-6 has an alternate input format, where reaches of the river can be subdivided into seven strips. Therefore variations in hydraulic conditions in the lateral direction can be grouped into different strips and a quasi-two-dimensional computation can be performed.

Input Data Requirements

The data needed to run the HEC-6 model can be classified into four categories (USACOE, 1977). These are:

1. Geometric data. Cross section coordinates, reach lengths, and Manning's n values for roughness are required for water surface calculations. In addition, the movable bed where the depth of sediment layers is specified is defined at each cross section.

2. Sediment data. Inflow sediment load rating curves, gradation of bed materials in the stream bed, and fluid and sediment properties are needed.

3. Hydrologic data. Data on water discharges, temperatures, durations of the flood, and computational intervals have to be inputted.

4. Operating rule. A relationship between discharges and water surface elevations (stage-discharge rating curve) or a rule curve can be specified at control cross sections. This stage-discharge rating curve or rule curve serves as a downstream boundary condition for the model. Such a relationship can be derived from records at gaging stations. It can also be derived from Manning's equation or from a critical depth assumption.

Peoria Lake Data for HEC-6 Application

1. Geometric data. The HEC-6 model for Peoria Lake includes data for the Illinois River from River Mile 160.75 just below the Franklin Street bridge to River Mile 181.90 just above Chillicothe (figure 14). Thirty-two cross sections measured within this reach by the Illinois State Water Survey (ISWS) in May and August 1987 were used in the HEC-6 model. In addition to these 32 cross sections, nine cross sections were added at places where there were sharp changes in channel geometry. The geometric coordinates for the nine additional cross sections were derived from linear interpolation between measured cross sections. Each cross section extends from 450 feet above mean sea level (msl) on the west bank to 450 feet msl on the east bank.

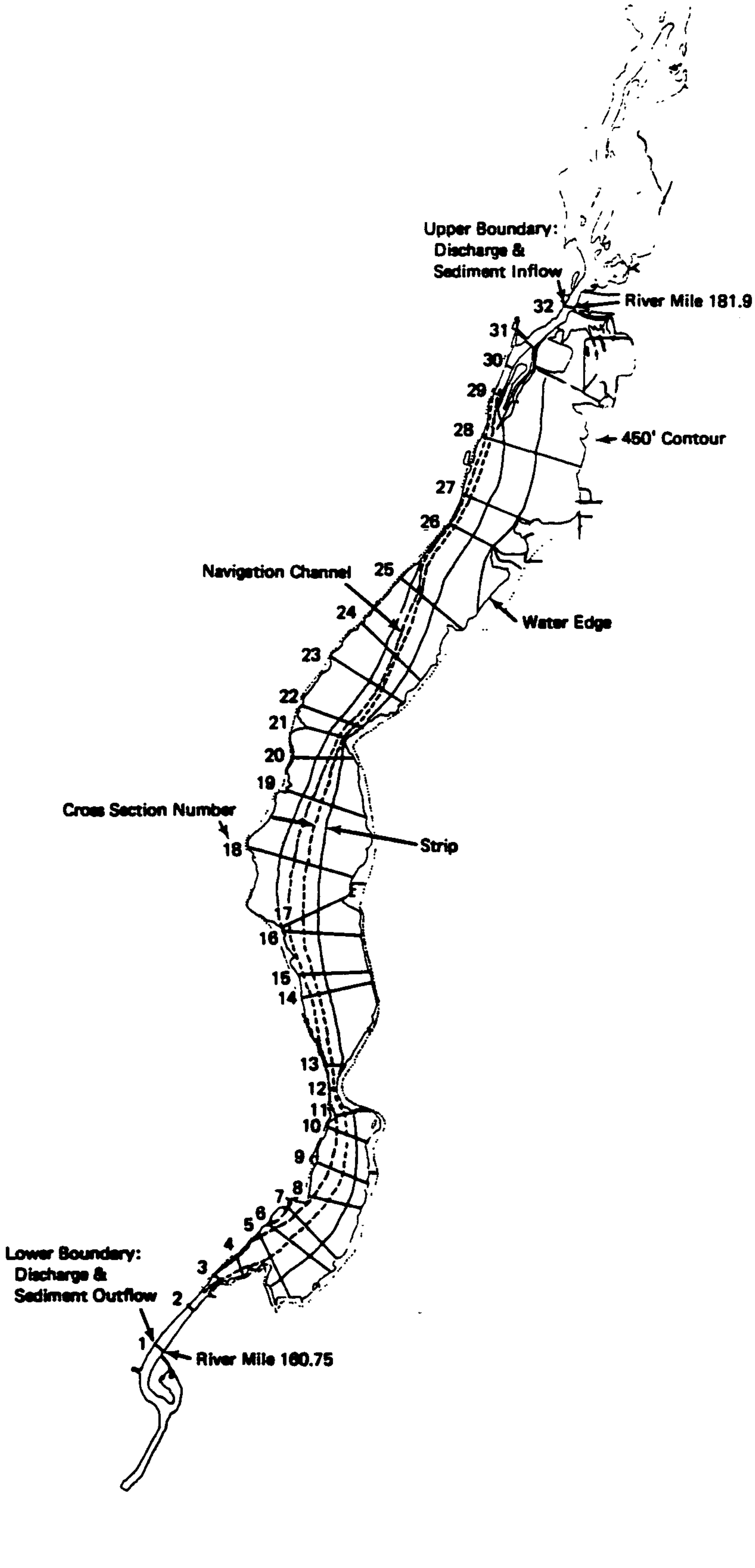

Figure 14. Locations of cross sections and strips used in the HEC-6 model

The HEC-6 alternative format was selected for the model. Generally, each segment is subdivided into five strips: one for the main channel, two for channel borders, and two for overbanks. As many as seven strips and as few as three strips were used. The locations of the cross sections and strips used are shown in figure 14. Different Manning's n values are assigned to the strips. The n values are assumed to vary with water stages. Typical values of n are 0.030 in the main channel, 0.032 in the channel border, and 0.035 at overbank for water stage at mean pool level. Different longitudinal distances between two cross sections are specified for each strip to account for the bends in the river.

2. Sediment data. Two sets of sediment data are required: inflow sediment load and gradation of bed materials at each cross section. Inflowing sediment load relations are developed from sediment load data taken from Water Resources Data for Illinois for Water Years 1985 and 1986 (USGS, 1985 and 1986). The suspended sediment data for the Illinois River at the Henry gaging station located at River Mile 196.0 were used to develop relations between water discharge and sediment load. The regression equation between suspended sediment load (Q_s, in tons per day) and discharge (Qw, in cfs) is:

$$\log(Qs) = -2.20 + 1.33 \log(Qw) \qquad (2)$$

where log is the logarithm to the base 10. The relation is plotted in figure 15 along with data points and me 95 percent confidence lines.

The percentages of sand, silt, and clay were estimated on the basis of a field measurement carried out by the ISWS in 1985 (Demissie et al., in preparation). These percentages are shown in table 2. The particle size distribution of the suspended sediment is 1 percent sand, 52 percent silt, and 47 percent clay. To determine the total sediment load, the suspended sediment load was increased by 15 percent to account for the contribution of the bed load to the total load (Simons and Senturk, 1977). Most of the bed load is assumed to be sand, and thus the percentage of sand in the total sediment load is 16 percent With this information, separate sediment rating curves for sand, silt, and clay can be derived from equation 2. The respective regression equations are as follows:

$$\log Qsd = -3.00 + 1.33 \log Qw \text{ (for sand)} \qquad (3)$$

$$\log Qst = -2.49 + 1.33 \log Qw \text{ (for silt)} \qquad (4)$$

$$\log Qcl = -2.53 + 1.33 \log Qw \text{ (for clay)} \qquad (5)$$

Qsd, Qst, and Qcl are the sand, silt, and clay loads respectively in tons per day.

The silt and sand fractions are further subdivided into different size classifications. Their relative percentages are given in table 3.

The bed material gradation data, also obtained from the Water Survey data (Demissie et al., in preparation), are shown in table 4.

3. Hydrologic data. The hydrologic data used in the HEC-6 model were obtained from flow records at Peoria and at the Henry gaging station on the Illinois River. Selected flows representing different flood frequencies and a full one-year hydrograph were used.

4. Operating rule. Since the stage-discharge rating curve at the Franklin Street bridge (River Mile 162.35) is known from Water Survey measurements, it is used as the downstream boundary condition for the model. This rating curve is shown in figure 16.

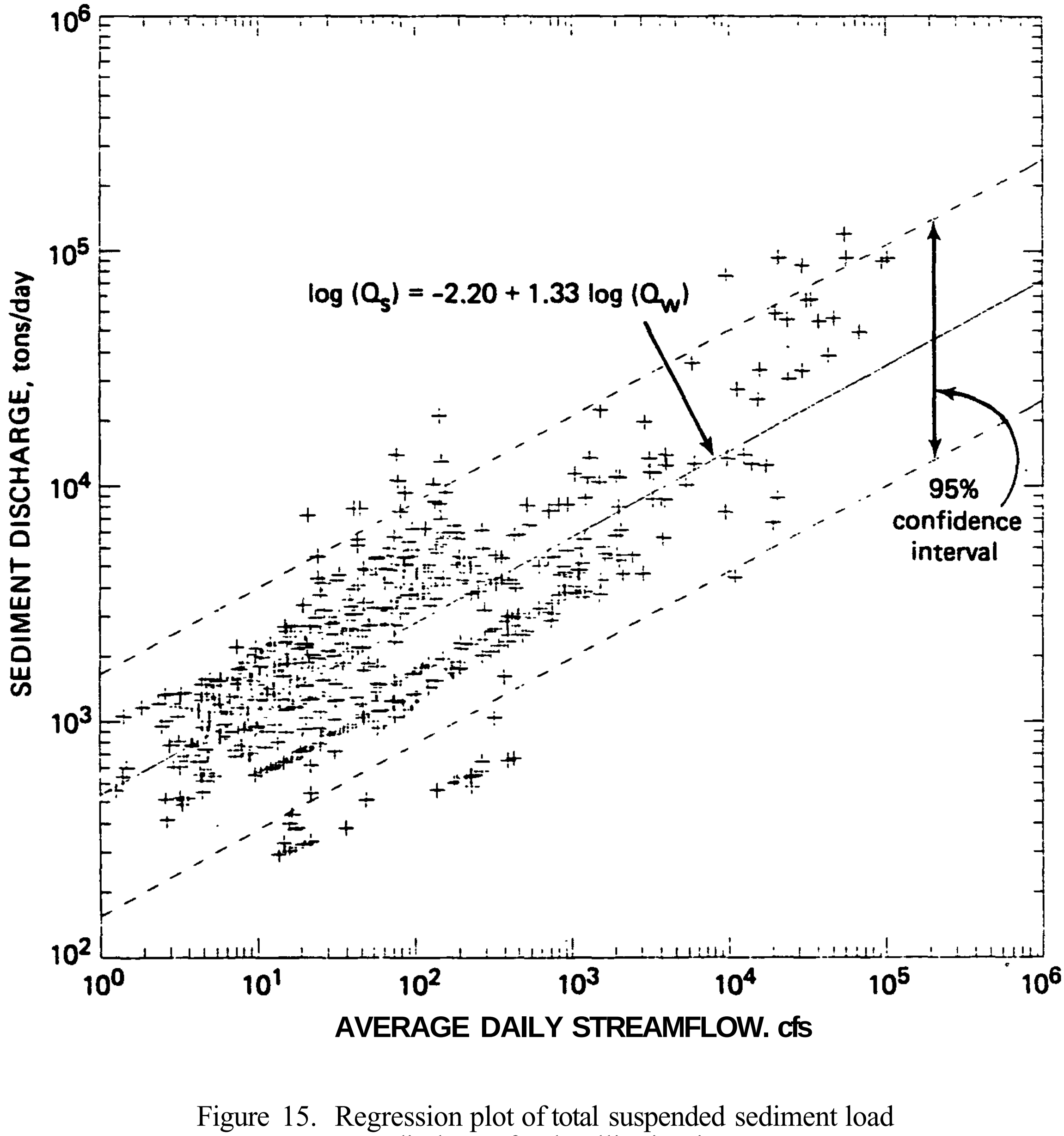

Figure 15. Regression plot of total suspended sediment load versus water discharge for the Illinois River at Henry

Table 2. Suspended Sediment Particle Size Distribution in the Illinois River at Peoria Lake

Size classification	Percent
Sand	1
Silt	52
Clay	47

Table 3. Sediment Size Classification for Silt and Sand

Silt		Sand	
Size classification	Percent	Size classification	Percent
Very fine	40	Very fine	85
Fine	30	Fine	10
Medium	20	Medium	5
Coarse	10		

Table 4. Bed Material Size Distribution in the Illinois River at Peoria Lake

Date data collected	Location (RM)	Distance from east shore (ft)	% sand	% silt	%clay
4/24/85	170.82	2390	2.3	46.0	51.7
4/24/85	170.82	4760	.4	46.8	.52.8
4/24/85	170.82	2325	.4	44.7	54.9
4/24/85	178.00	6871	4.0	63.4	32.6
4/24/85	178.00	2567	1.4	49.3	49.3
4/24/85	178.00	1262	.5	42.4	57.1
4/24/85	182.00	midpoint	99.9		
4/24/85	182.00	west 1/4 point	99.4		
4/24/85	174.90	1192	.17	46.92	52.91
4/24/85	174.90	2513	0.81	55.55	43.64
4/24/85	174.90	4317	14.16	59.66	26.18

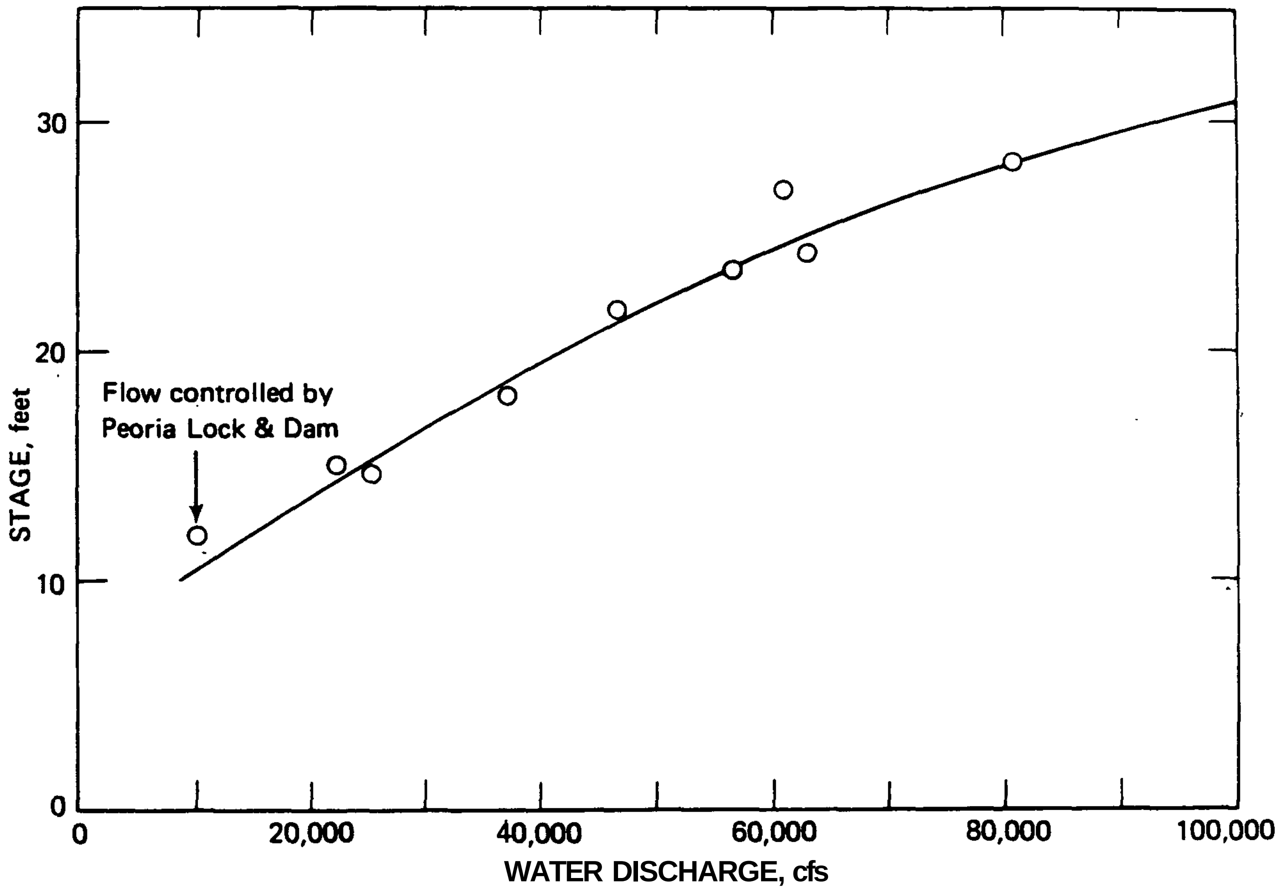

Figure 16. Stage-discharge rating curve for the Illinois River at the Franklin Street bridge in Peoria

Calibration and Application of the HEC-6 Model for Peoria Lake

Calibration of the HEC-6 model for Peoria Lake included comparing water surface elevations at selected locations to determine if me parameters selected for the model were appropriate. For Peoria Lake, water surface elevations measured at the U.S. Army Corps of Engineers boat yard (River Mile 164.3) were used to calibrate the model. The results of the calibration process are shown in figure 17, in which the computed and measured water surface elevations are compared for the flood in May and June 1987. As shown in the figure, the model reproduced the flood elevations very well. Therefore it was felt that the geometric and hydraulic parameters selected for the HEC-6 model were satisfactory and thus the model could be used to investigate Peoria Lake.

The HEC-6 model was used to perform the following tasks:

1. To determine water surface elevations along Peoria Lake for different discharges and island locations and sizes.

2. To investigate the change in sedimentation rates due to the construction of artificial islands for different flow conditions and island locations and sizes.

The HEC-6 results for the above investigations are presented in the "Results and Discussion" section.

TABS-2 Model

Model Description

TABS-2 is a generalized numerical model for studying depth-averaged two-dimensional hydrodynamics, transport, and sedimentation problems in rivers, reservoirs, bays, and estuaries. TABS-2 contains a series of programs represented schematically in figure 18 (Thomas and McAnally, 1985).

The three major modules of the TABS-2 model are the hydrodynamics, sediment, and transport modules. The preprocessor and postprocessor modules are used to manipulate and prepare input and output information. The hydrodynamics module performs the flow field computations such as flow velocities and water depth in two dimensions. The sediment module performs the sediment transport computations by using the results from the hydrodynamics module. The transport module performs neutrally buoyant substance transport by using the results from the hydrodynamics module. The hydrodynamics module can also be used by itself without interacting with the sediment or transport modules, as shown in the schematic in figure 18.

TABS-2 not only solves more complicated equations than HEC-6, in two-dimensional computation, but also has a different modeling method from that of HEC-6. TABS-2 divides the study area into elements. Each element consists of several nodes. All computations are performed at each node. In the horizontal plane, the x and y coordinates of each node determine its location in the prototype, and the z coordinate specifies the elevation. The size of the element can be varied according to the complexity of the flow area and the need for detailed data. Thus in an area where more detailed information is required or where flow velocities are expected to vary rapidly, the element sizes are made small so that there will be more nodes in the area where detailed computations are needed.

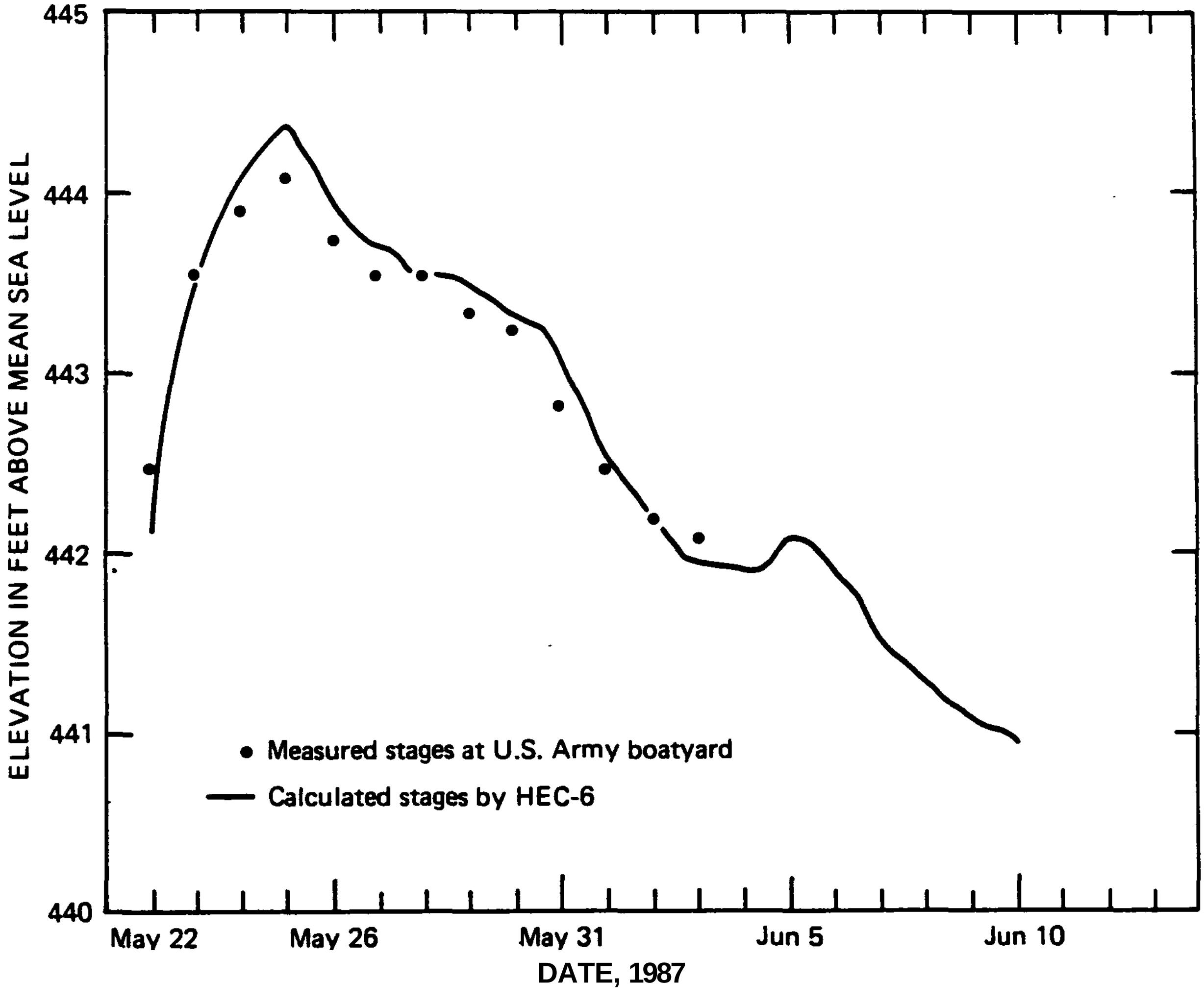

Figure 17. Comparison of computed water stage and measured water stage at cross section 8

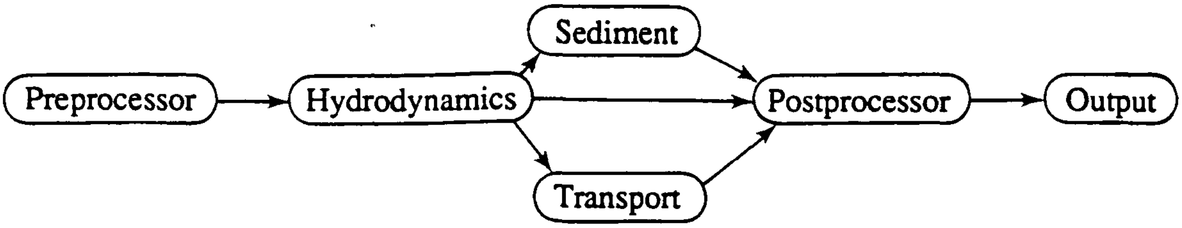

Figure 18. Schematic representation of the major components of TABS-2

By definition for a depth-averaged model, all variations of parameters in the z direction are integrated over the depth to determine the average value. Therefore, TABS-2 is not applicable to problems where variations in velocity and concentrations along the depth are significant.

Input Data Requirements

Since only the results of the hydrodynamics module of TABS-2 are presented in this report, only the data requirements for this module will be discussed. It should be emphasized, however, that the hydrodynamics module is always required for both the sediment and transport modules. Data needed to run the hydrodynamics module of TABS-2 include: finite element mesh, hydrodynamic properties, boundary condition, initial condition, and computational control. A brief discussion of each of these data groups follows.

1. Finite element mesh. The finite element mesh is the basic geometric data for TABS-2. It defines the relationship between the model and the prototype, limits the boundaries of computation, and controls the details of computation. In the preprocessor module for preparing the input data (figure 18), one defines the area to be modeled from a map, outlines the desired divisions for regions on the map, and then digitizes the boundary around each region. Once the map has been digitized, programs in the preprocessor module are used to generate an element mesh, an element connection table, and the horizontal coordinates for each node. After optimization of the element numbering sequence, the element mesh used in the model is determined. At areas where sudden changes in hydraulics are expected, one can use more elements. The types and number of elements used at one area should represent the degree of expected fluctuations in hydraulics at that area. After an appropriate bed elevation is added to each node, the finite element mesh controls both lateral and vertical boundaries of the study area.

2. Hydrodynamic properties. Hydraulic properties such as Manning's n, turbulence coefficient, and wind shear stress coefficient are needed. Manning's n is a description of boundary roughness. It can be assigned by element or by element type, or a constant value can be assigned to the entire mesh. The turbulence coefficient relates to the momentum exchange due to velocity gradients, and is assigned by element types. The wind shear stress coefficient is a measure of shear stress exerted on the water by wind and is assigned by nodes when needed.

3. Boundary condition and initial condition. Boundary conditions are specified at external nodes. They can be either water surface elevation, water discharge, or flow velocity. All solutions found at internal nodes have to match the boundary conditions. The initial condition is the initial depth of water and velocity at every node and needs to be specified to start the computation.

4. Computational control. Computational controls such as convergence parameters, iteration controls, and computational interval need to be specified. Convergence parameters tell the program when to stop a solution-seeking process, iteration control prevents a run-away execution, and computational interval determines the numerical stability of the computation.

Peoria Lake Data for TABS-2 Application

1. Geometric data. Because of the limitations on computer memory on the CYBER 175 at the University of Illinois, the whole lake could not be modeled at once. Thus two segments of Peoria Lake were selected for detailed modeling using TABS-2. These two segments are the areas which were identified as the best locations for building islands and side channels. The first segment is in Lower Peoria Lake from River Mile 164.5 to 166.3, while the second segment is in Upper Peoria Lake between River Miles 169.75 and 173.15.

The two regions modeled and the finite element mesh used for the model are shown in figures 19 and 20 (Lower and Upper Peoria Lakes, respectively). The finite element mesh was modified for each particular condition modeled. When islands and side channels were added to the model, the finite element mesh was modified accordingly. For the basic no island condition, there were 274 elements and 887 nodes for the Lower Peoria Lake region and 250 elements and 781 nodes for the Upper Peoria Lake region. As islands and side channels were included, the number of elements and nodes was increased.

2. Hydrodynamic properties. Based on the strip division information from the HEC-6 model, each segment modeled was divided into four different regions and Manning's n values were assigned for each region. The division and corresponding Manning's n for the regions in the Lower Peoria Lake model are: 1) main channel, n = 0.027,2) channel border, n = 0.030, 3) shallow zone, n = 0.035, 4) area near edge of water, n = 0.040. In the Upper Peoria Lake model, similar divisions and Manning's n values were used. The turbulence coefficients in all directions are assumed to be 100 lb-sec/ft2 for elements in the main channel, 200 lb-sec/ft2 for elements in the channel side, 300 lb-sec/ft2 for elements in the shallow zone, and 400 lb-sec/ft2 for elements near the water edge. Wind effect is not used at this stage of the study.

3. Boundary condition and initial condition. At the inflow boundary, velocity is specified as boundary condition for all nodes on the input cross section. Appropriate magnitudes of velocity for each node are derived from the carrying capacity concept (Chow, 1959). Inflow direction is measured from the map and adjusted to the model. For all boundary nodes on the two water edge sides, either parallel flow condition or stagnant flow condition is specified, depending on whether the node is on a smooth boundary or on a sharp comer. At the downstream cross section, the water stage was used as the boundary condition. Water stages were obtained from the HEC-6 analysis. Because the water surface slope in Peoria Lake is not significant, the initial condition assumed a constant water surface elevation 1 foot higher than the downstream stage.

4. Computational control. Only steady state computations were performed for this study. All convergency parameters and iteration control values used were as suggested in the user manual of the TABS-2 model.

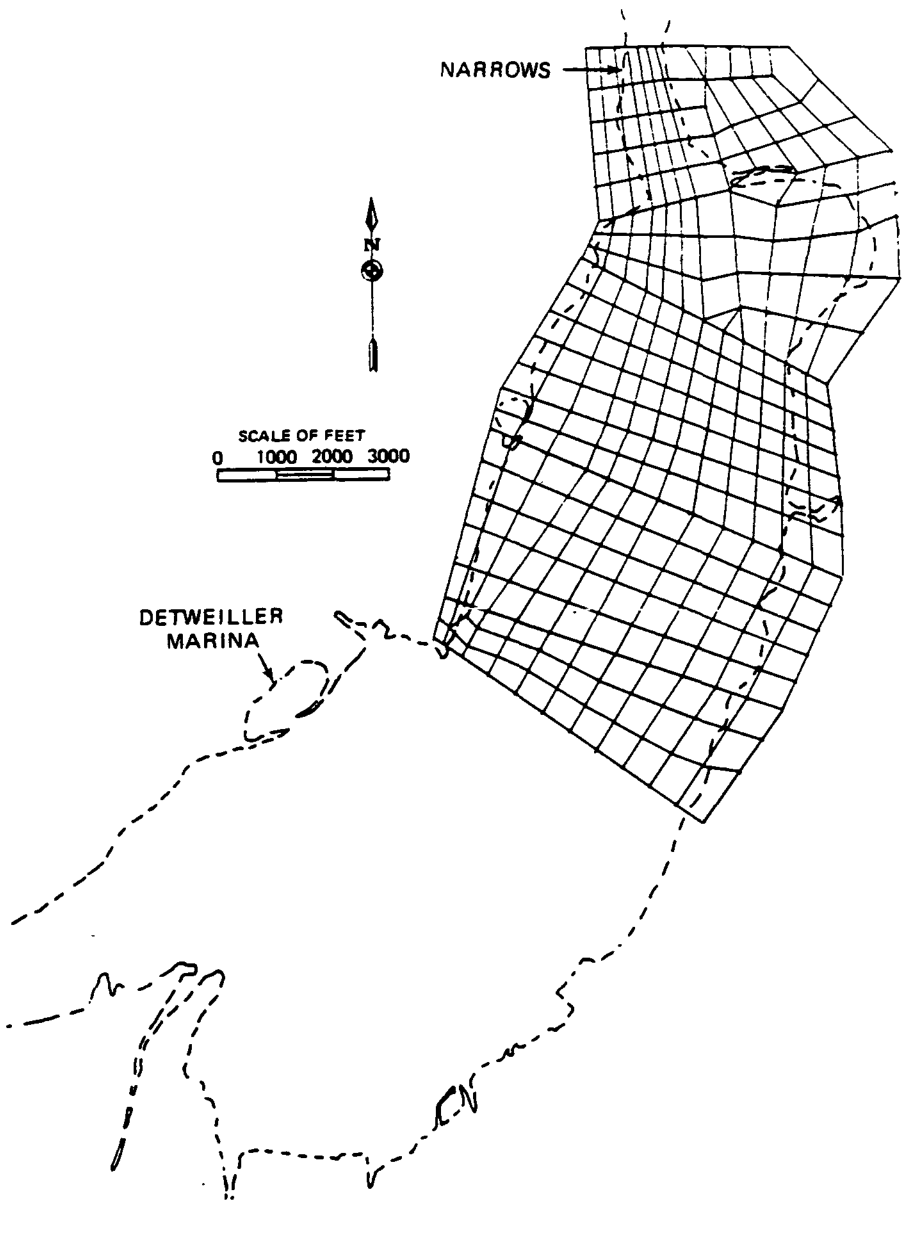

Figure 19. Finite element mesh for the TABS-2 model in Lower Peoria Lake

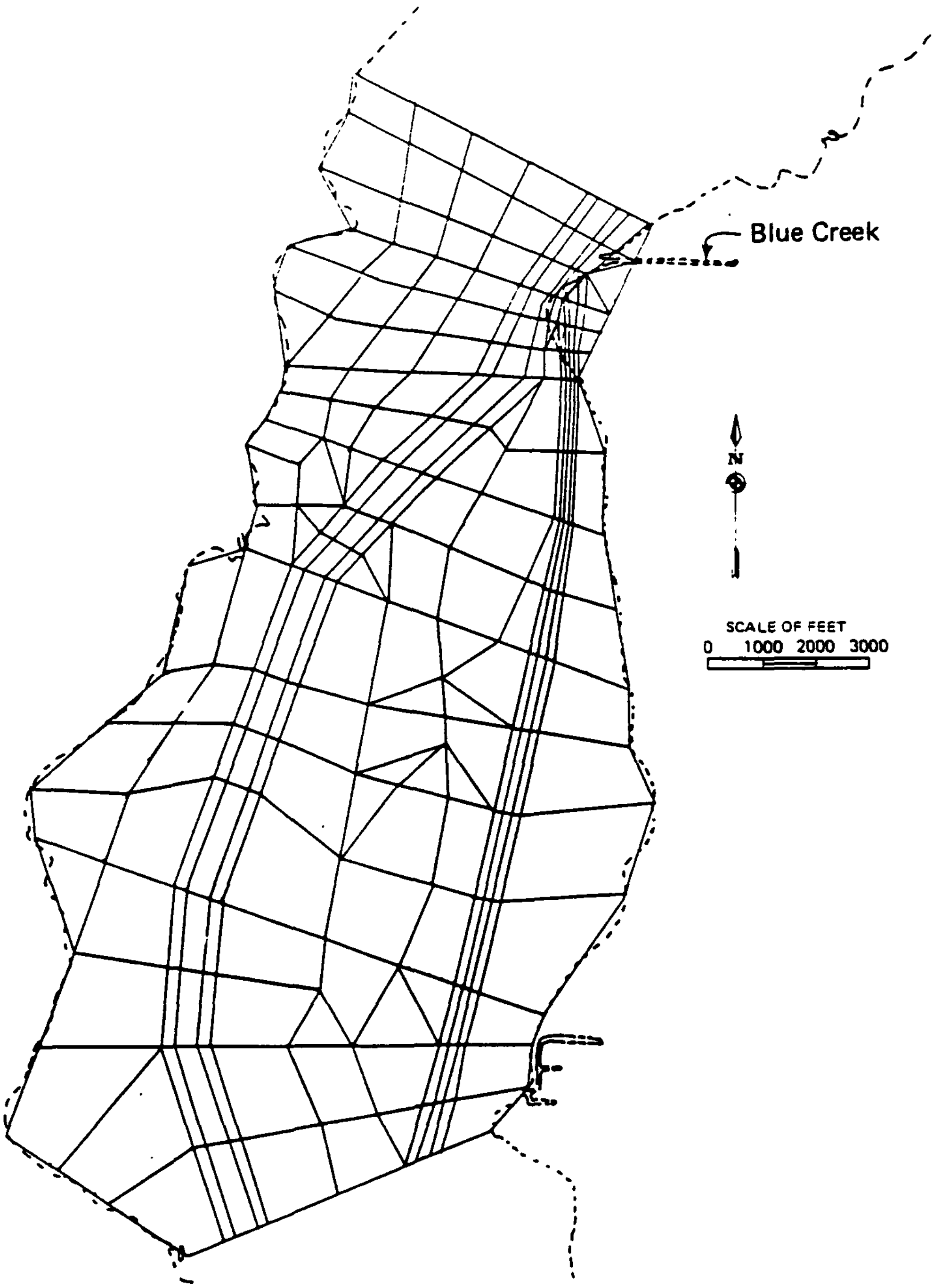

Figure 20. Finite element mesh for the TABS-2 model in Upper Peoria Lake

Calibration and Application of the TABS-2 Model for Peoria Lake

Calibration analysis for the TABS-2 model involved comparing water surface profiles generated by TABS-2 with those generated by HEC-6 for given discharges. Figure 21 is a comparison of the water surface profiles for Lower Peoria Lake computed by the TABS-2 and HEC-6 models for three discharges. Figure 22 is a similar comparison for the Upper Peoria Lake model. The results shown in the figures demonstrate that the TABS-2 model reproduces the HEC-6 results very well and thus can be assumed to have been calibrated based on comparison with HEC-6 results. After the TABS-2 model was calibrated, it was used to investigate the changes in water surface profiles, velocity, and discharge distributions including flow through the side channel configurations. The major changes in the models ' involved for modeling different conditions were in finite element mesh generation. Where islands and side channels are proposed, the finite element sizes and elevations at impacted nodes are all changed for each particular case.

The results of the TABS-2 model are presented in the following section along with the HEC-6 results.

Results and Discussion

The HEC-6 and TABS-2 models were used conjunctively to investigate the hydraulic impacts of constructing islands in Peoria Lake. The two models complement each other in many ways. For a general overall view and for sediment transport, the HEC-6 was used. When more detailed hydraulic information was needed, the TABS-2 was used. It should be pointed out that the TABS-2 model costs much more to run than the HEC-6 model, and to run the TABS-2 model for the whole lake would have been too expensive and was unjustified at this stage of the project.

The modeling strategy used in this project was as follows:

1. Develop the HEC-6 model for the whole Peoria Lake from River Mile 160.75 to River Mile 181.90, and run the model to obtain water surface elevations at selected locations and to analyze sedimentation in Peoria Lake.

2. Develop the TABS-2 model for the two short reaches identified earlier to investigate the hydraulic impacts of islands and side channels in more detail. Information generated in step 1 is used as input boundary conditions in TABS-2.

3. Modify HEC-6 geometric data input to incorporate islands and side channels, and investigate the scour or deposition of sediment in both the main channel and side channel. The flow division between the main channel and side channel is obtained from TABS-2 computations in step 2.

Conditions Investigated

In addition to existing conditions, several different assumed configurations of islands and side channels were modeled for both Lower and Upper Peoria Lake. The different assumptions pertained to island size, number of islands, island orientation, and location of islands.

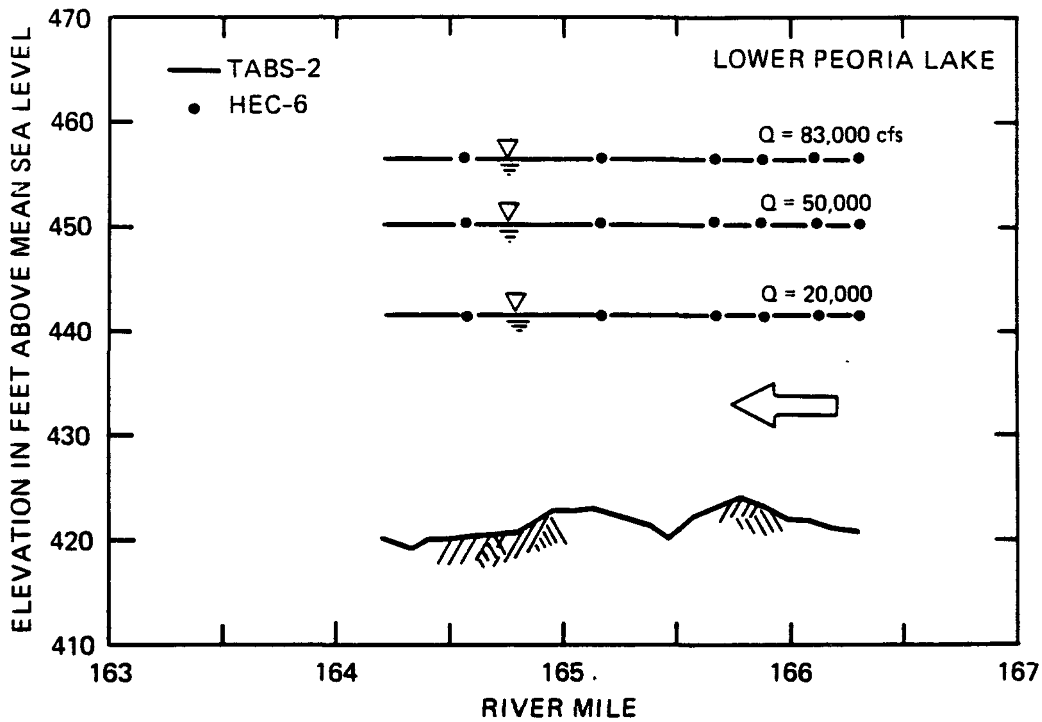

Figure 21. Comparison of water surface profiles calculated by TABS-2 and HEC-6 for Lower Peoria Lake

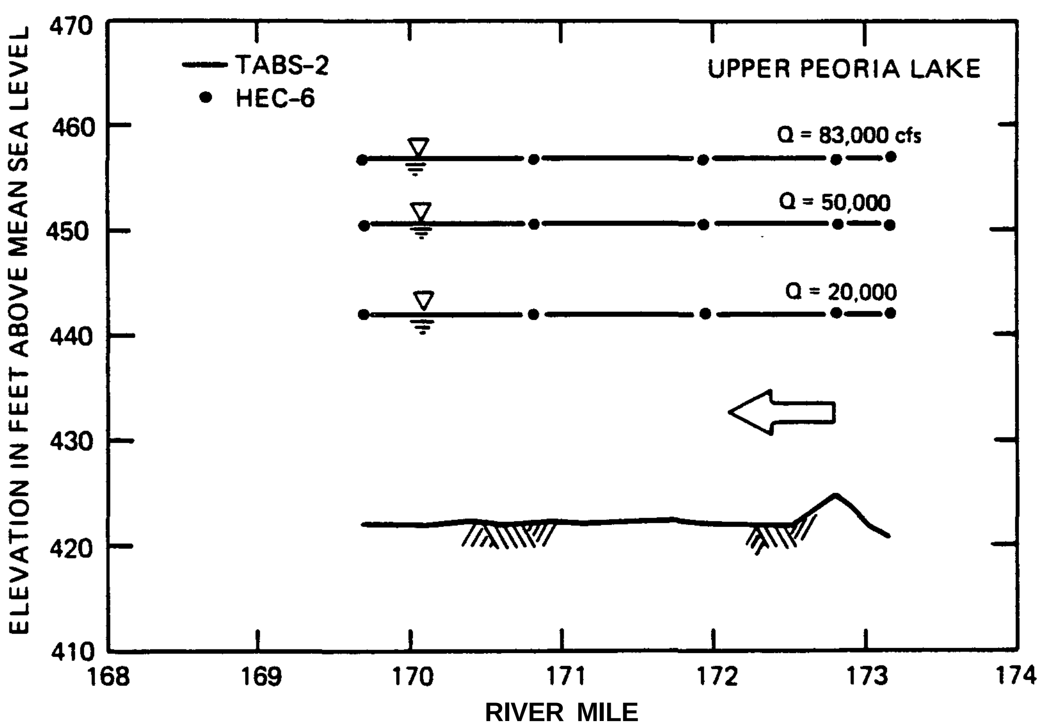

Figure 22. Comparison of water surface profiles calculated by TABS-2 and HEC-6 for Upper Peoria Lake

Six different island and side channel configurations (shown in figure 23) were modeled in Lower Peoria Lake:

1. The base model, referred as the no island condition.
2. Inclusion of an island about 500 feet downstream of the Highway 150 bridge. The size of the island was approximately 14 acres. This is called the small island condition.
3. An increase in the size of the island to 32 acres. This is referred to as the large island condition.
4. Rotation of the upper end of the large island toward the main channel. This is referred to as the rotated island condition.
5. Addition of another island of the same size downstream of the rotated island. This is referred to as the two islands condition.
6. Consideration of only the downstream island. This is referred to as the lower island condition. In addition to the islands, a side channel was always included as part of the design, as shown in the figure. The side channel was assumed to have a maximum depth of 6 feet and the same slope as the main channel.

In Upper Peoria Lake, four different island configurations (illustrated in figure 24) were tested. They are similar to the conditions in Lower Peoria Lake, but the islands are larger. Using similar terminology as for the lower lake, the four island configurations in the upper lake are:

1. no island
2. upper island (the area of the island is 135 acres)
3. two islands (the area of the lower island is 142 acres)
4. lower island only

The side channel in Upper Peoria Lake was assumed to have a maximum depth of 6 feet and the same slope as the main channel. The models were generally run for three different flow conditions in the river. The three flows selected were 20,000 cfs for low flow; 50,000 cfs, which is close to the 5-year flood; and 83,000 cfs, which is the 50-year flood for high flow (Lardner et al., undated).

HEC-6 Modeling Results

The hydraulics of the whole Peoria Lake under existing conditions was first investigated by using the HEC-6 model. The water surface profiles along the lake for the three flows considered are shown in figure 25. Under low flow conditions (20,000 cfs), the water surface profile in the lake is nearly flat with a slope of 1.2 inches/mile. As the flow increases, the water surface slope also increases slightly, reaching 1.4 inches/mile for the high flow condition (83,000 cfs). It is also interesting to note the influence of the restricted segments of the river on the water surface profile. The influence of the constrictions at the downstream end, at the narrows, and at the upper end can easily be noticed from the water surface profile for the high flow.

The HEC-6 model was then used to investigate sedimentation in Peoria Lake. Since sedimentation has to be investigated over a long period of time instead of through static evaluations for selected flows, the 1985 water year flow hydrograph of the Illinois River at

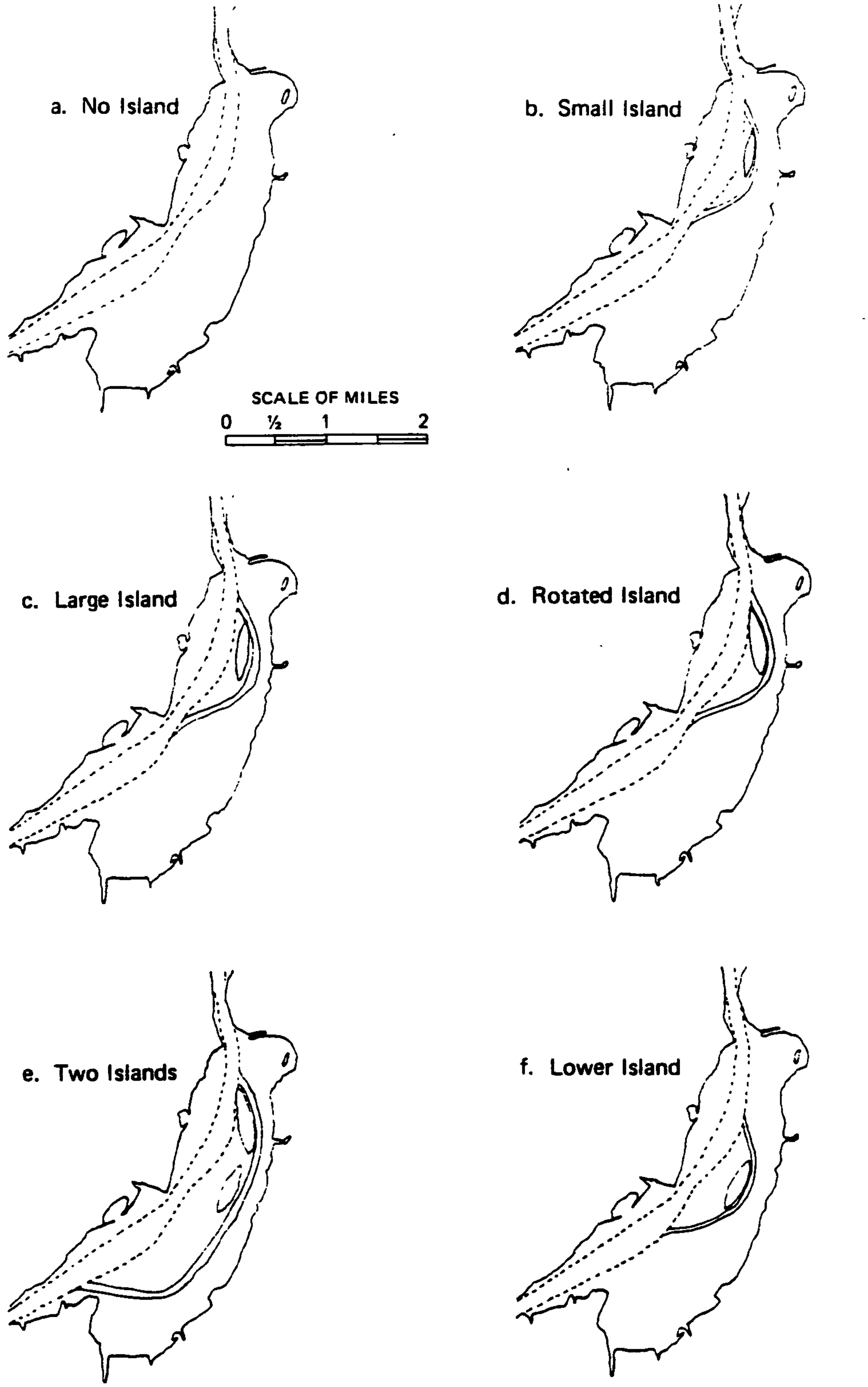

Figure 23. Various island and side channel combinations investigated in Lower Peoria Lake

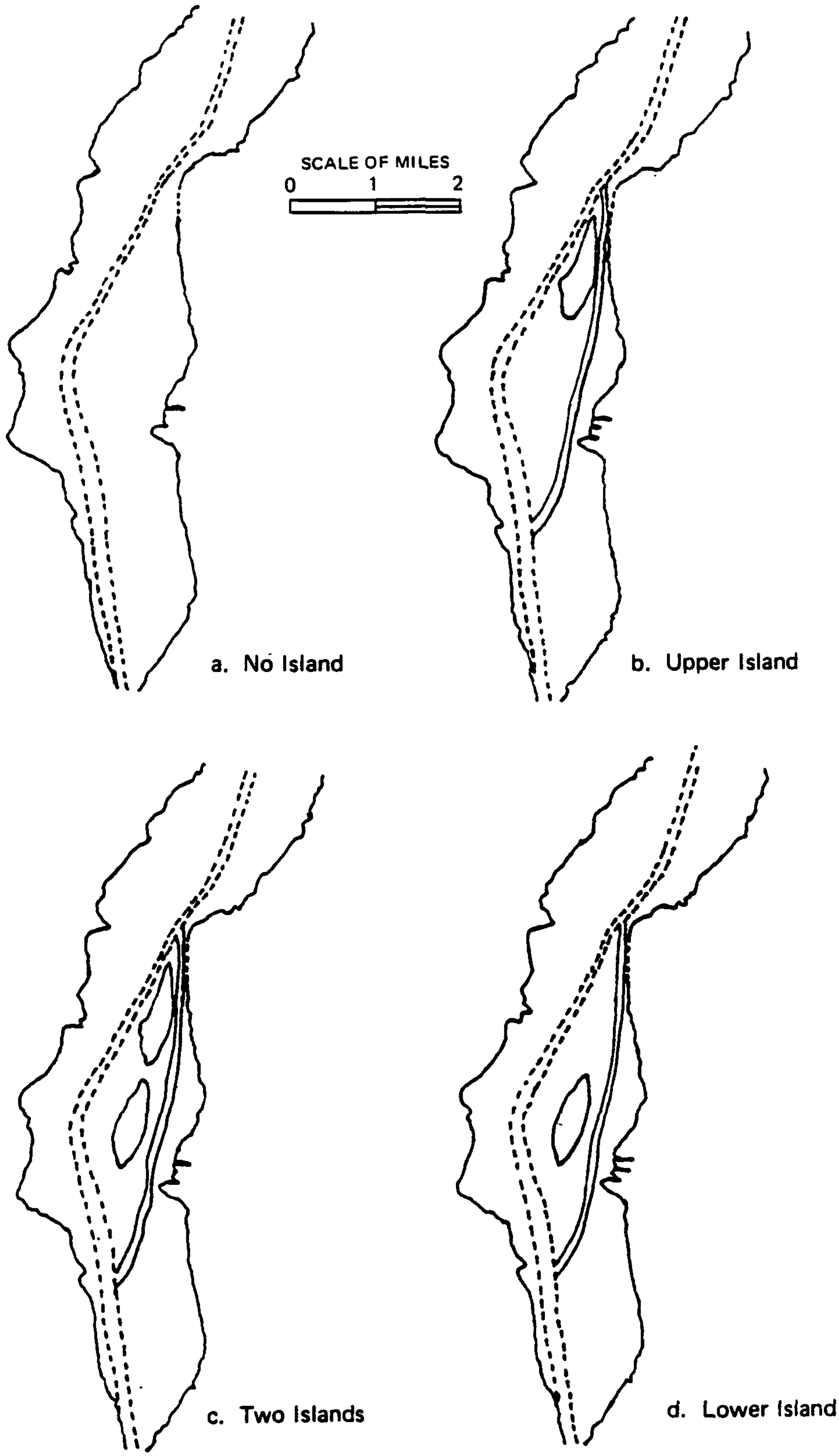

Figure 24. Various island and side channel combinations investigated in Upper Peoria Lake

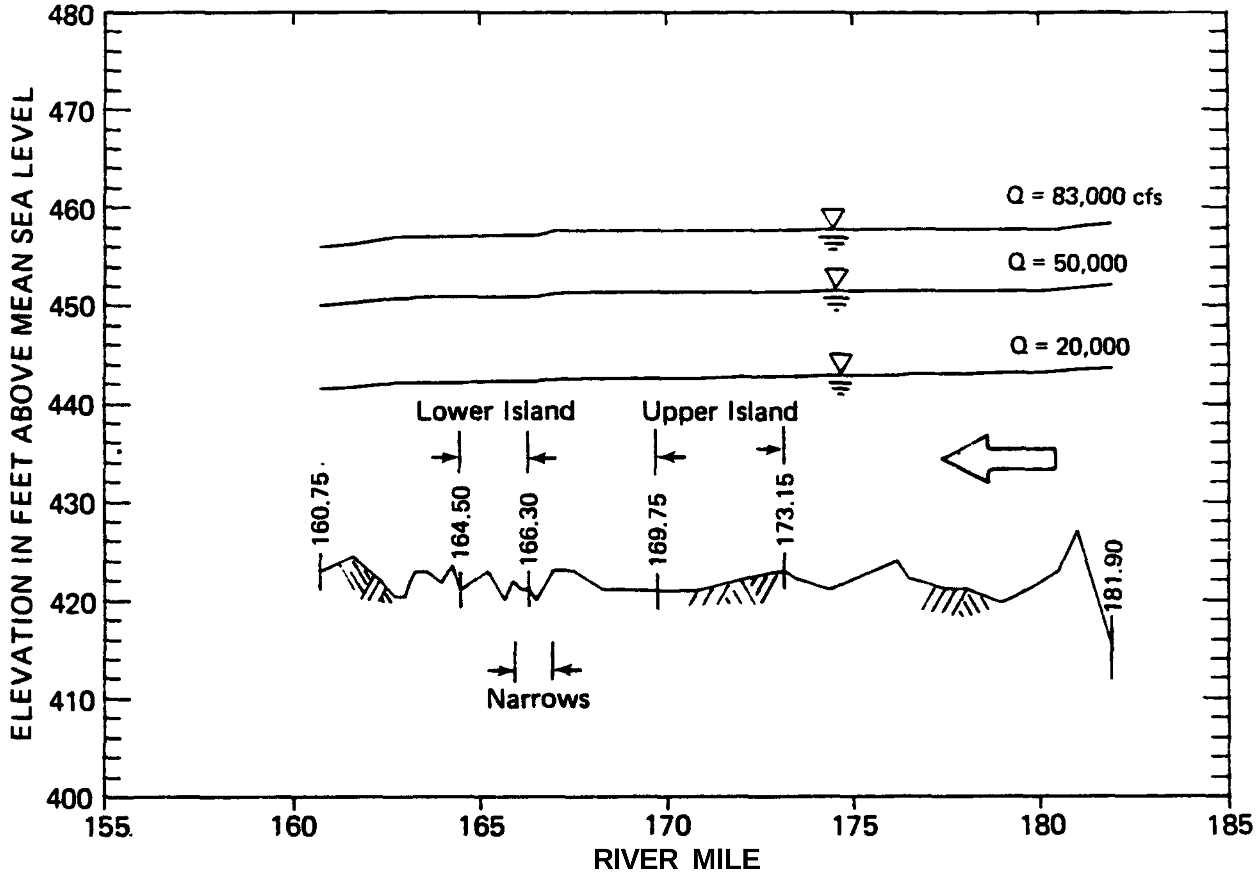

Figure 25. Water surface elevations in Peoria Lake
based on HEC-6 simulation

Henry (USGS, 1985) was used to model sedimentation in the lake with and without islands. The flow hydrograph was discretized into 33 discrete discharges of variable duration, as shown in figure 26, and routed through Peoria Lake. The same sediment load equations and sediment characteristics discussed earlier were used with the hydrograph. The sedimentation results after a year like the 1985 water year are summarized in figure 27, where the expected change in channel bed elevation along the Illinois River in Peoria Lake is shown. The model shows a significant channel bed elevation increase in Upper Peoria Lake. The bed change shown in the figure is limited within the moveable bed width specified in the program and is not spread laterally over the entire lake width. Thus the channel bed elevation changes shown in the figure might not really be observed in the channel. Another factor that will affect the distribution of the sediment in the channel is the presence of navigation, which resuspends the sediment and moves it in the lateral direction out of the channel.

A more important analysis for this study is the comparison of the sedimentation rates in the lake with and without islands. This comparison is shown in figure 28, in which the simulated bed elevations in the Illinois River after routing the 1985 water year hydrograph with and without an island are compared. As can be seen in the figure, there is not much difference between the two situations in terms of sedimentation in the main channel.

The impact the islands might have on water surface elevations in Peoria Lake was also investigated by comparing the simulated water surface elevations along the lake for the high discharge of 83,000 cfs (50-year flood) with and without an island. The result is shown in figure 29, where the water surfaces for the two conditions practically overlap, indicating that the island would have no significant impact on water surface elevations in the lake. According to the HEC-6 results, the maximum difference in water surface elevations between the with and without an island conditions was only 0.01 foot

TABS-2 Modeling Results

The TABS-2 model was run for the six different configurations in Lower Peoria Lake (figure 23) and for the four different configurations in Upper Peoria Lake (figure 24). The TABS-2 results include water surface elevations and velocity vectors for the regions modeled. Flow distributions can also be determined from the velocity distributions.

The results from the TABS-2 simulations included in this report are:

1. Velocity vector distribution for each of the conditions modeled.
2. Velocity distributions along selected cross sections.
3. Division of flow between the main channel and the side channel.
4. Water surface profile comparisons between the no island condition and the conditions with islands.

Because of the large number of illustrations needed to represent the results for all the conditions investigated, only a few of the figures are included in the main part of the report The rest of the figures are included in the appendices.

The velocity vector distributions for the no island condition and the large island condition in Lower Peoria Lake during a flow of 50,000 cfs in the river are shown in figures 30 and 31, respectively. As can be seen by comparing the figures, the changes in the velocity field are localized near the island. The flow directions are altered near the island, especially at the upper end of the island. The induced changes are more significant during high flows than during low flows. The velocity vector plots generated for the different combinations of flows and island configurations are presented in Appendix A.

Similar plots for the no island and upper island conditions in Upper Peoria Lake are shown in figures 32 and 33 for a discharge of 50,000 cfs. The rest of the figures for the different conditions are included in Appendix A. Here again the changes in velocity field are localized around the island and do not seem to have much impact farther away from the island.

Since the large velocity vector plots shown in figures 30 through 33 show the changes in velocity direction very well but do not show the changes in the magnitude of the velocity as well, velocity distributions along selected cross sections were compared on different figures. For this comparison, six cross sections in Lower Peoria Lake and five cross sections in Upper Peoria Lake were selected. The locations of the cross sections with respect to the islands are shown in figures 34 and 35 for Lower Peoria Lake and Upper Peoria Lake, respectively. The cross sections were chosen so that changes in velocity could be compared at the upstream end, at the middle, and at the downstream end of the islands.

The results were plotted as shown in figures 36, 37, and 38 for Lower Peoria Lake. The figures show a comparison of the velocity along cross section 2 (shown in figure 34) for the existing condition (no island) and for one island in Lower Peoria Lake for three different discharges. Also shown in these figures are the existing bed profiles along with the modified profiles mat include islands and a side channel. As can be seen in the figures, the hydraulic impact of constructing islands and side channels in Lower Peoria Lake (as shown in figure 23) will be to increase the flow velocity in the main channel and in the side channel. The increase in velocity increases as the discharge increases. It is important to notice, however, that the maximum velocity in the main channel for the high flow of 83,000 cfs with one island is only 1.64 ft/sec. The maximum velocity in the side channel under the same conditions is only 0.93 ft/sec. The maximum velocities in the main channel and side channel for the three flow conditions and the different island configurations in Lower Peoria Lake are given in table 5. The velocities are those from cross section 2, located near the middle of the upper island. In all cases the maximum velocities are less than 2 feet per second. Comparisons of velocities for the different island configurations and flows for two cross sections are included in Appendix B.

A similar set of comparisons for the situation in Upper Peoria Lake is shown in figures 39, 40, and 41 for the same tiiree discharges. Similar to the Lower Peoria Lake condition, when an island and side channel are included the velocities increase both in the main channel and in the side channel area over tiiose for the existing condition. Here again, although velocities increase as compared to existing conditions, they are not very high. The maximum velocities at cross section 2 for the tiiree different discharges are given in table 6. The maximum velocities are all less than 1.5 ft/sec. In Upper Peoria Lake, because of the main channel alignment and the location of the island, the velocity in the side channel tends to become greater than the velocity in the main channel as flow increases.

Additional comparisons of velocities at two cross sections for the different configurations and flows are included in Appendix B.

In general, it can be concluded that construction of islands and side channels in Peoria Lake would increase the flow velocities in both the main channel and side channel, but would not generate excessively high flow velocities. This conclusion is important because it implies that the main channel and side channel in the vicinity of the islands would transport sediment more efficiendy than under existing conditions, and thus sedimentation rates in tiiose areas would be reduced slighdy. At the same time the increased velocities generated by the islands would not be so high that they would cause excessive scour and threaten the stability of the islands.

Flow Distribution between the Main Channel and Side Channel

In addition to flow velocities, the split of the flow between the main channel and the side channel is an important consideration in locating the islands and side channels. The flow distribution can be calculated from the velocity outputs of TABS-2 and the channel geometry data. The percentages of the total flow passing through the side channel for different island configurations and flows are shown in figures 42 and 43 for Lower Peoria Lake and Upper Peoria Lake, respectively.

In Lower Peoria Lake, the percentage of flow in the side channel varies from a low of 8 percent for Q = 20,000 cfs and one large island to a high of 24 percent for Q = 83,000 cfs and one small island. In general the percentage of flow in the side channel increases as the total flow increases and tends to attain a stable maximum at high flows. For the large islands the maximum percentage is about 19 percent, while for the small island situation the percentage is about 24 percent

For Upper Peoria Lake, the percentage of flow in the side channel varies from a low of 14 percent for one island at 20,000 cfs to a high of 21 percent for high flows. The split of flow between the main channel and side channel is not significantly different whether mere are one or two islands.

The flow distributions determined here are of course dependent on the assumptions and geometric specifications. They will provide a guide to a more detailed modeling and determination of flow distributions as the size and location of an island become more definite.

Changes in Water Surface Elevations

Since me water surface profiles generated by HEC-6 are not as detailed as those generated by TABS-2 for the areas where islands are proposed, a closer examination of the changes in water surface elevations induced by the islands was performed by using the TABS-2 results. The results of such analyses are shown in figures 44 and 45 for Lower and Upper Peoria Lakes, respectively. For both Lower and Upper Peoria Lakes, the case of one large island under three different flow conditions is presented. The rest of the comparisons for different conditions are presented in Appendix C. In all cases considered, there is a slight drop in water surface elevations in regions where mere are islands, but the drop is not significant (the maximum drop is 0.08 feet).

Summary and Conclusions of the Hydraulic Analyses

The hydraulics of Peoria Lake depends on its geometric characteristics, on the flow in the Illinois River, and on the operation of the lock and dam system of the Illinois Waterway. Because of Peoria Lake's location on the Illinois River where the stream gradient is extremely flat and the width very large, flow velocities through the lake are small. As a result, the lake has had a high sedimentation rate.

The construction of islands and side channels was found to have only localized hydraulic impacts. It did not change the hydraulics of flow or the sediment transport characteristics of the Illinois River away from the islands. In the areas where islands were located it was found that flow velocities increased both in the main channel and in the proposed side channels. However, because of the naturally small flow velocities in most parts of Peoria Lake, the maximum velocities generated due to island construction were not very high even during high flows in the Illinois River. Therefore the local increase in velocity is expected to improve the sediment transport capacity of the river in the areas where islands are proposed, without threatening the stability of the islands.

The islands and side channel can be designed so that a desired percentage of the total flow in the river passes through the side channel. For the conditions considered in this report, the percentage of flow in the side channel varied from a low of 8 percent to a high of 24 percent These percentages of course will depend on the size and orientation of the islands and the side channels in addition to the flow rate in the river.

The impact of the islands on water surface elevations was also investigated in detail. The analysis shows that there would be a slight decrease of water surface elevations in the areas where islands are proposed and no significant change upstream or downstream of the islands. This is consistent with the velocity results.

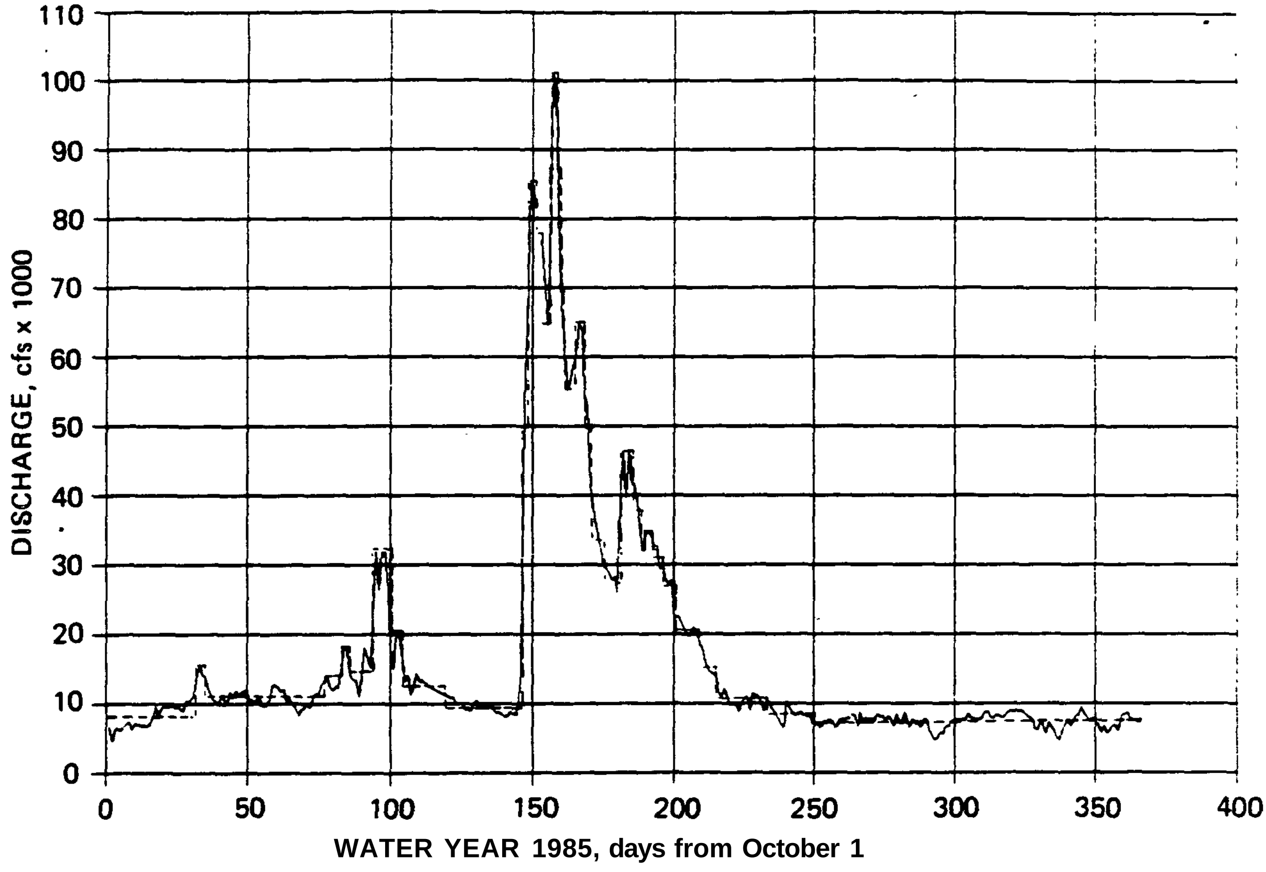

Figure 26. 1985 flow hydrograph of the Illinois River at Henry

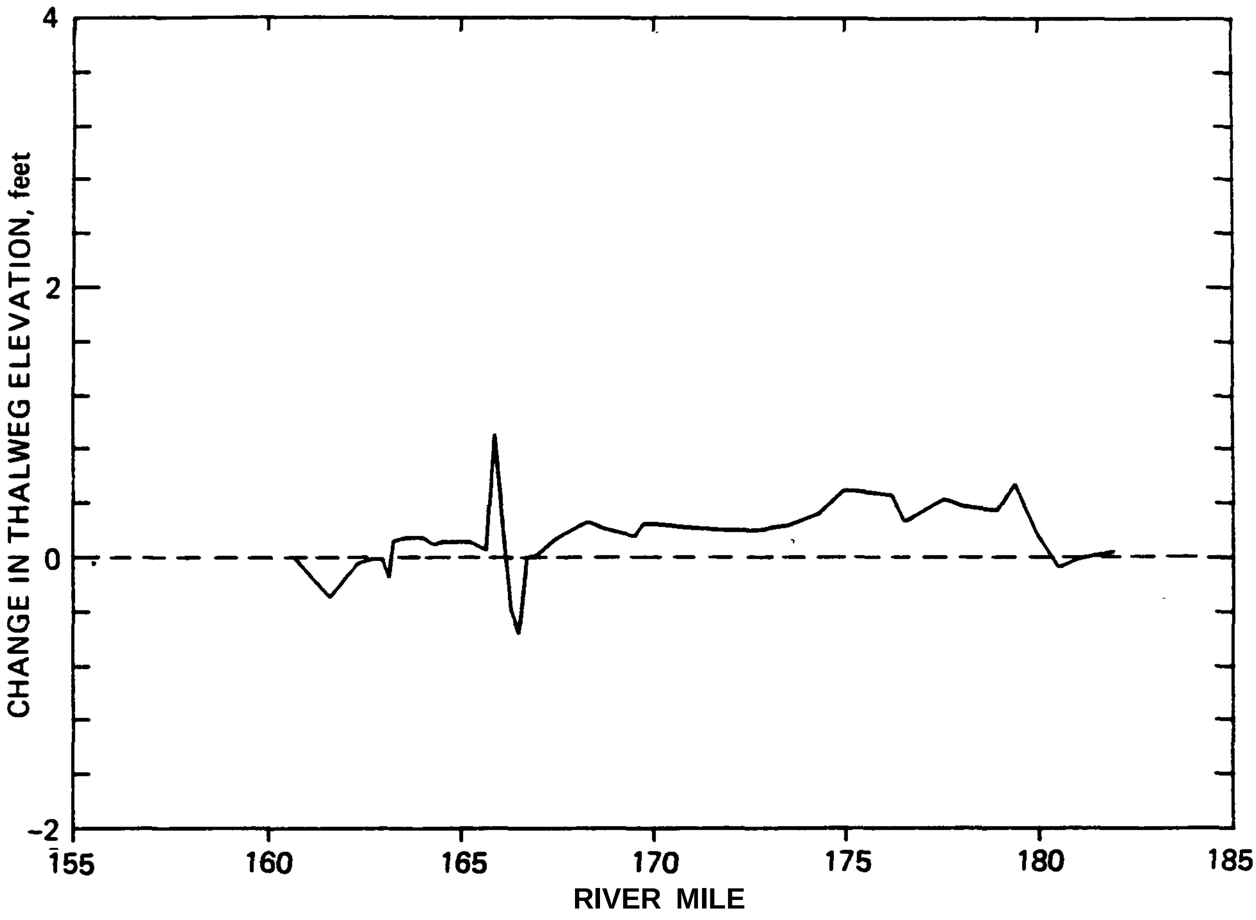

Figure 27. Change in channel bed elevations simulated by HEC-6
at the end of a one-year hydrograph

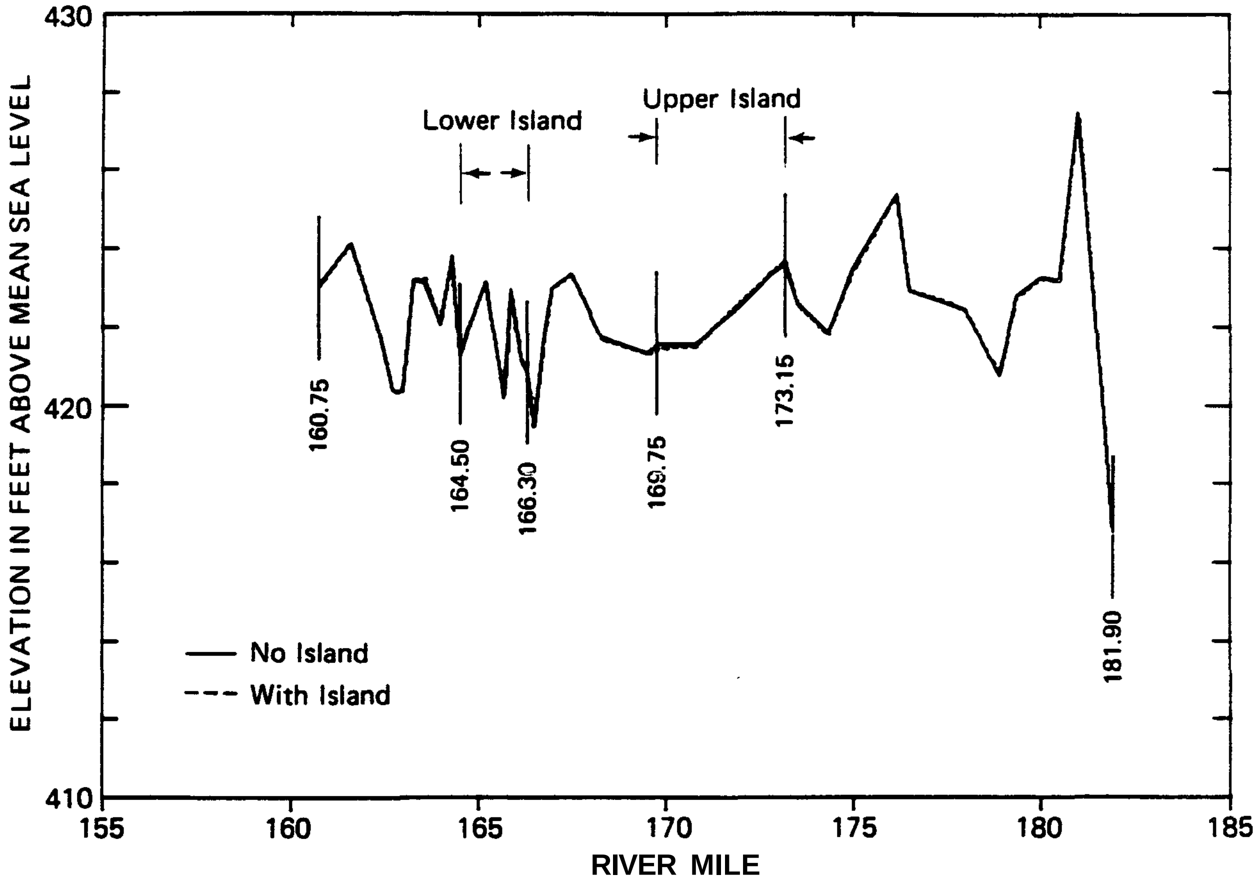

Figure 28. Comparison of channel bed elevations for <u>no island</u> and <u>with island</u> conditions as simulated by HEC-6 at the end of a one-year hydrograph

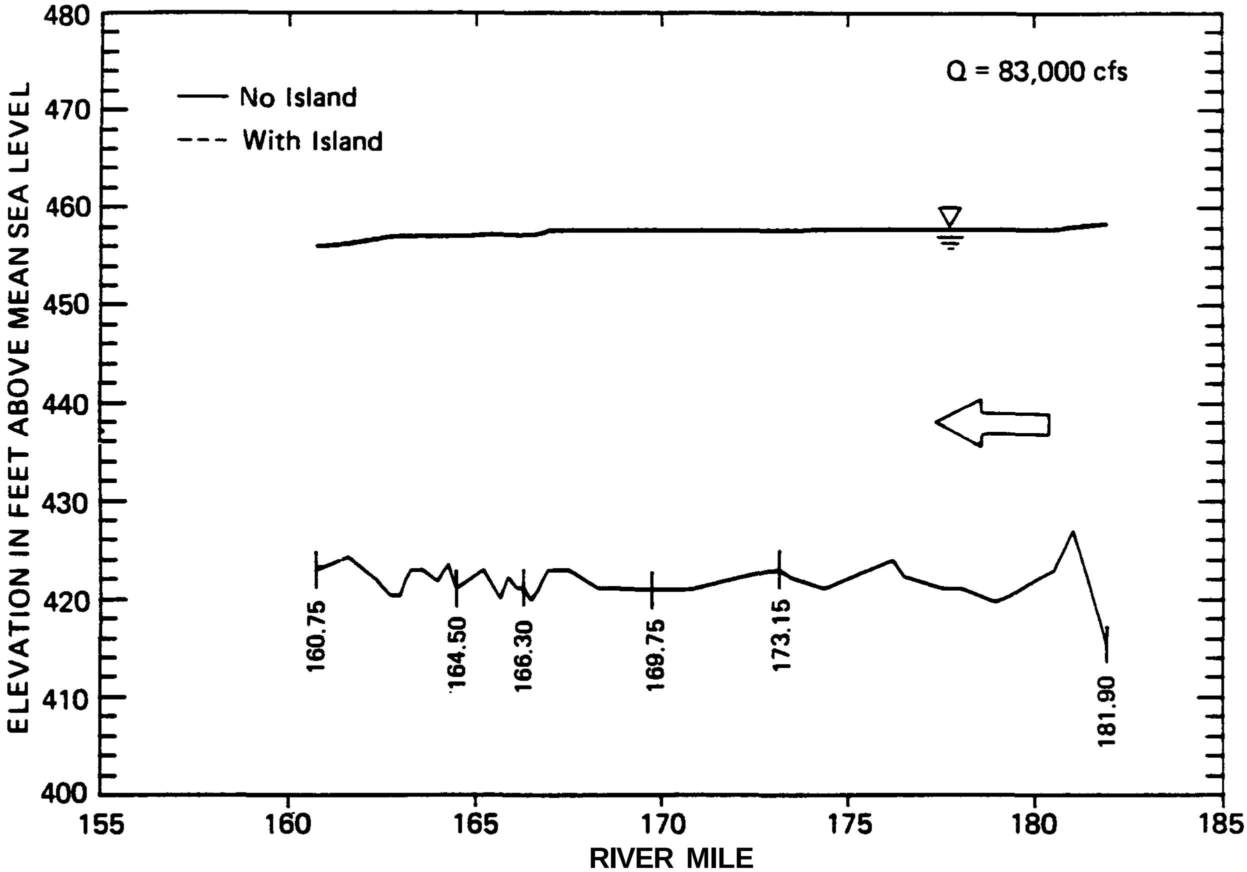

Figure 29. Comparison of water surface elevations for no island and with island conditions as simulated by HEC-6 for Q = 83,000 cfs

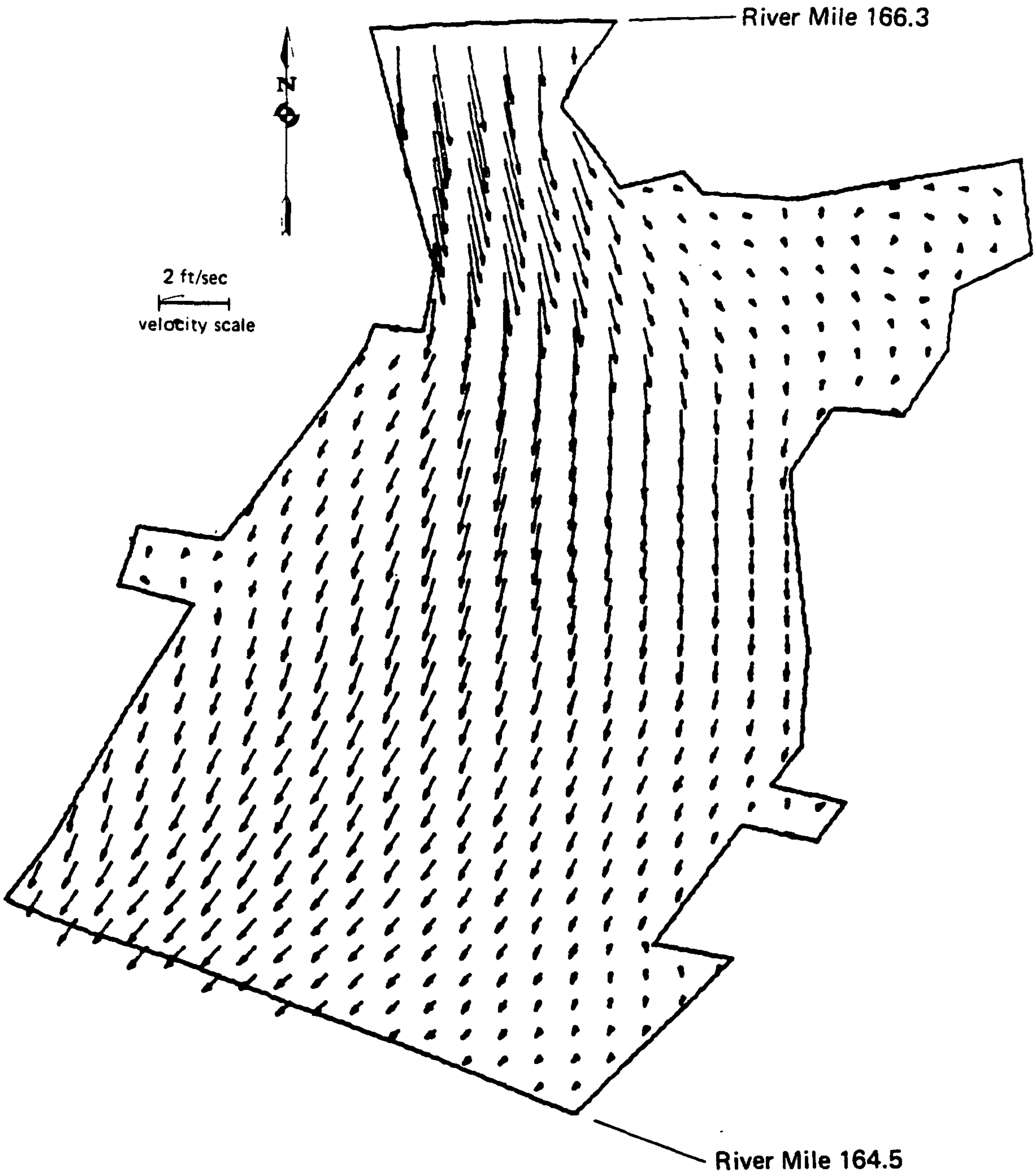

Figure 30. Velocity vector field for the no island condition in Lower Peoria Lake based on TABS-2 simulation for Q = 50,000 cfs

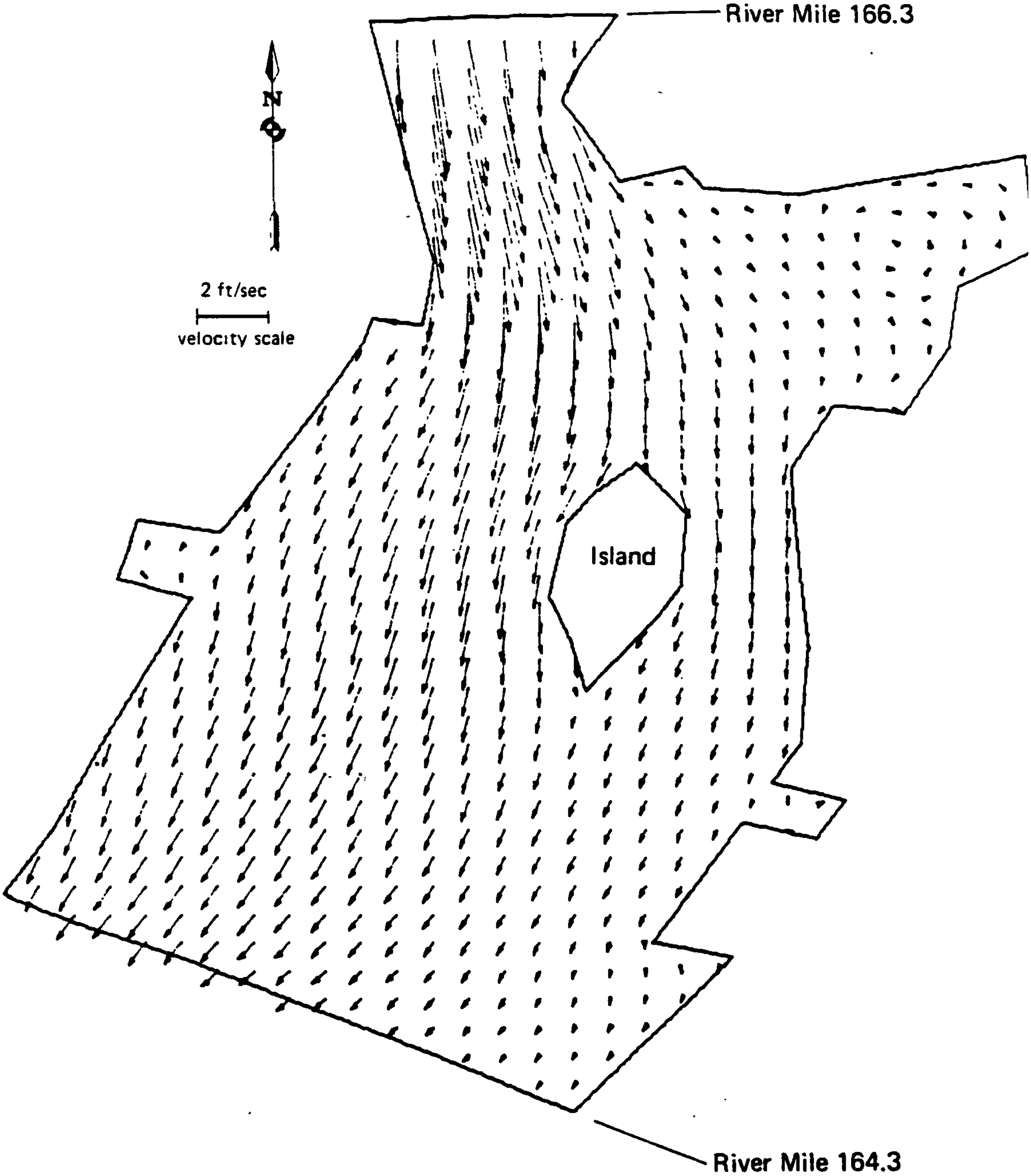

Figure 31. Velocity vector field for the large island condition in Lower Peoria Lake based on TABS-2 simulation for Q = 50,000 cfs

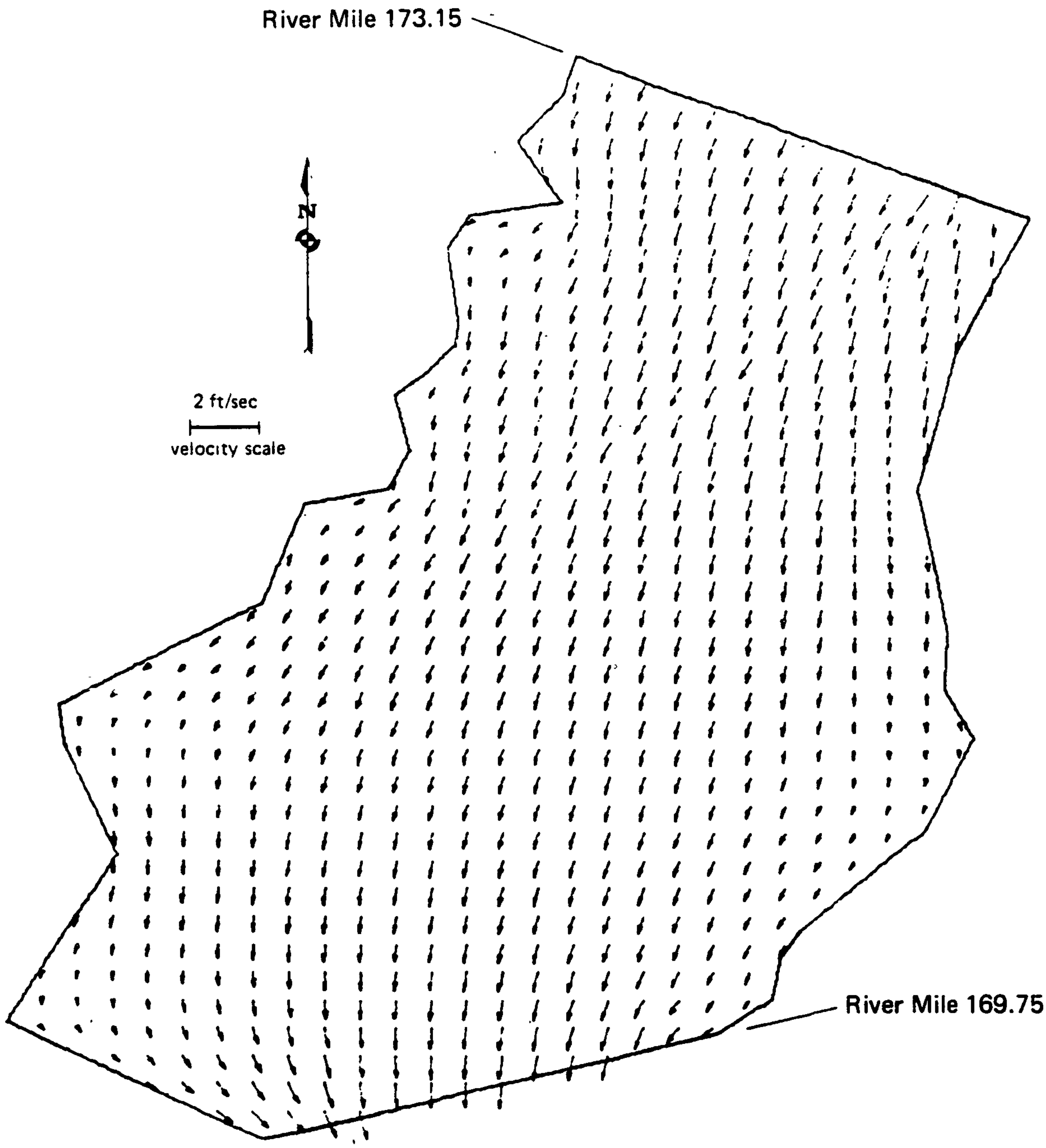

Figure 32. Velocity vector field for the no island condition in Upper Peoria Lake based on TABS-2 simulation for Q = 50,000 cfs

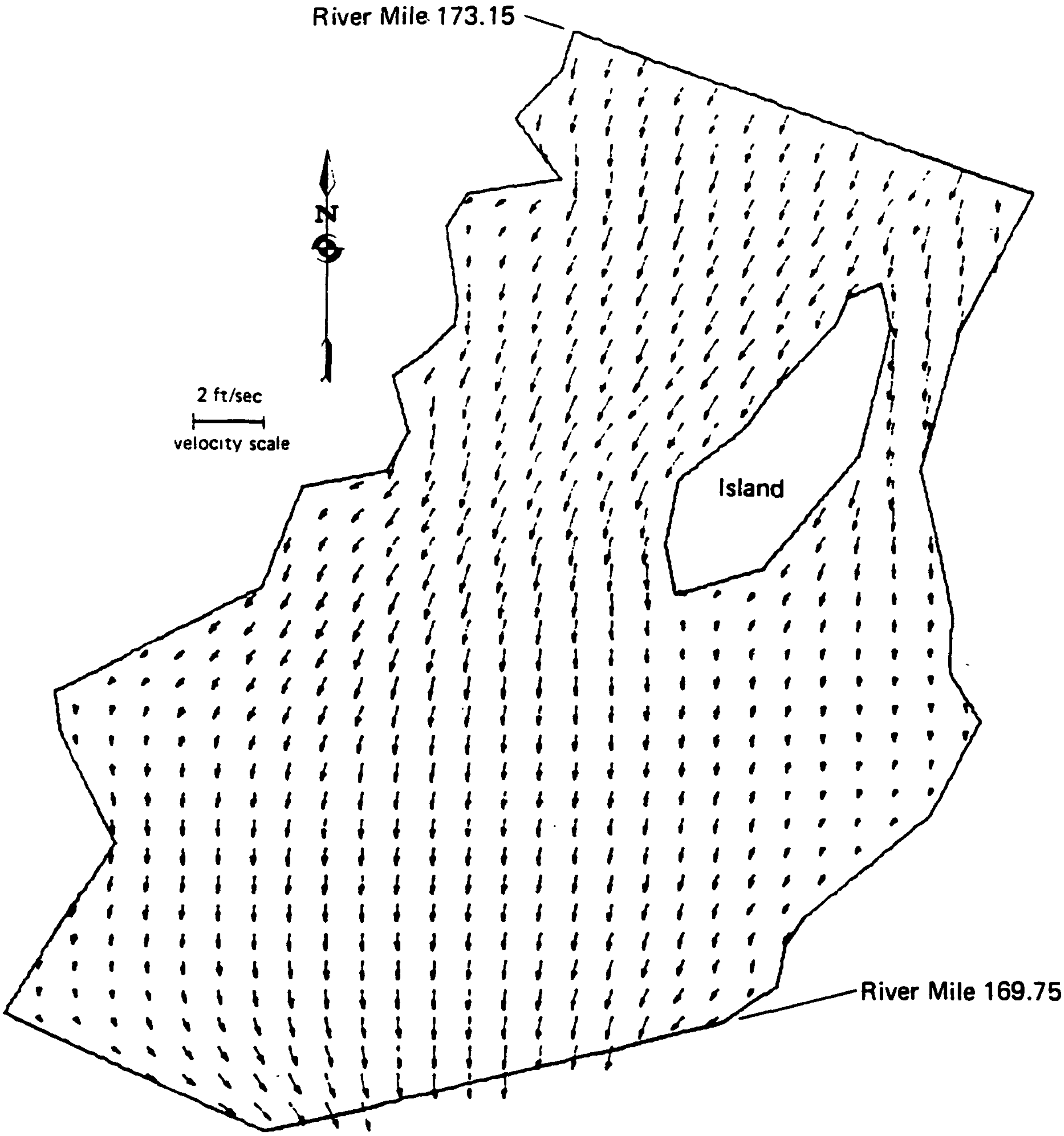

Figure 33. Velocity vector field for the upper island condition in Upper Peoria Lake based on TABS-2 simulation for Q = 50,000 cfs

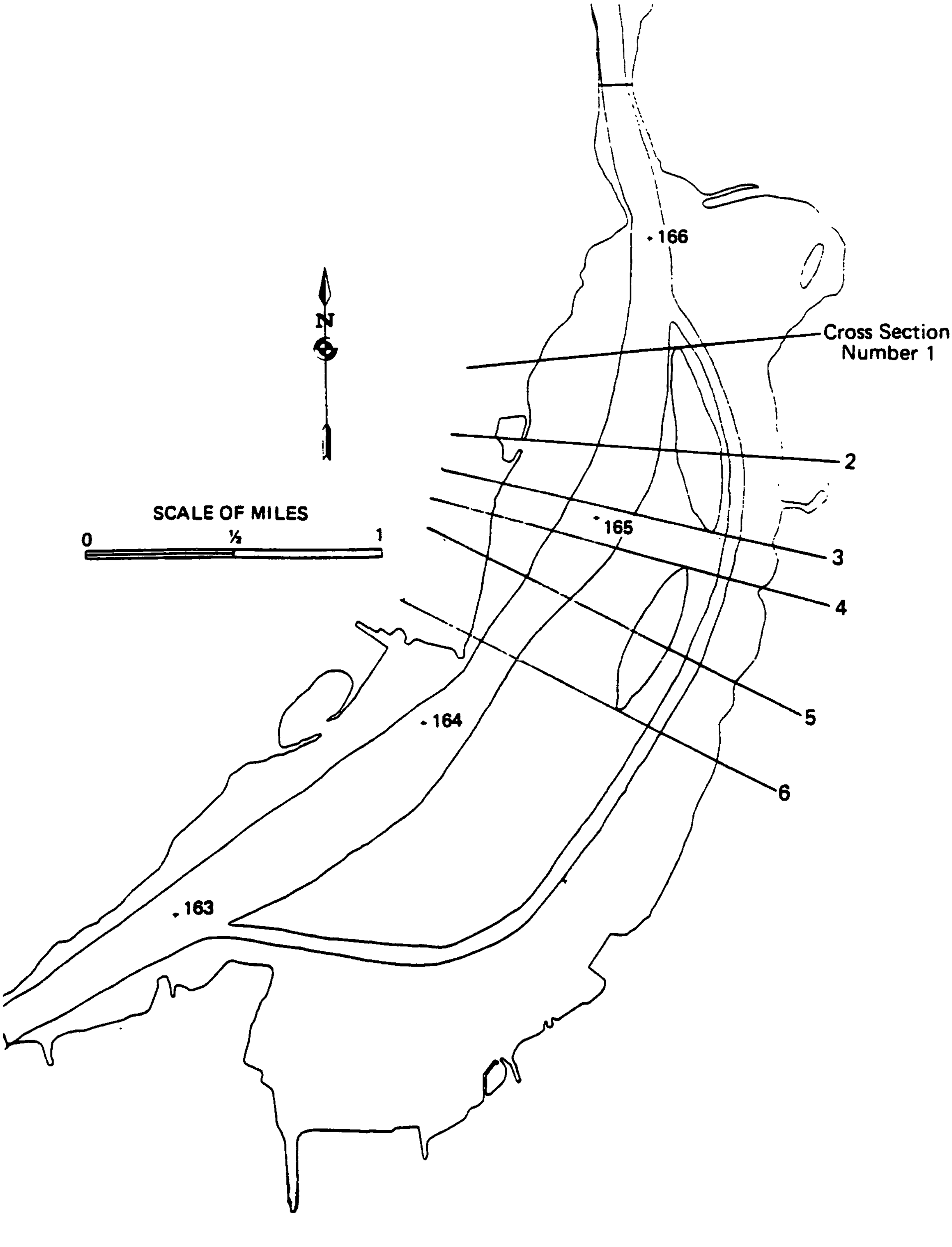

Figure 34. Locations of selected cross sections in Lower Peoria Lake

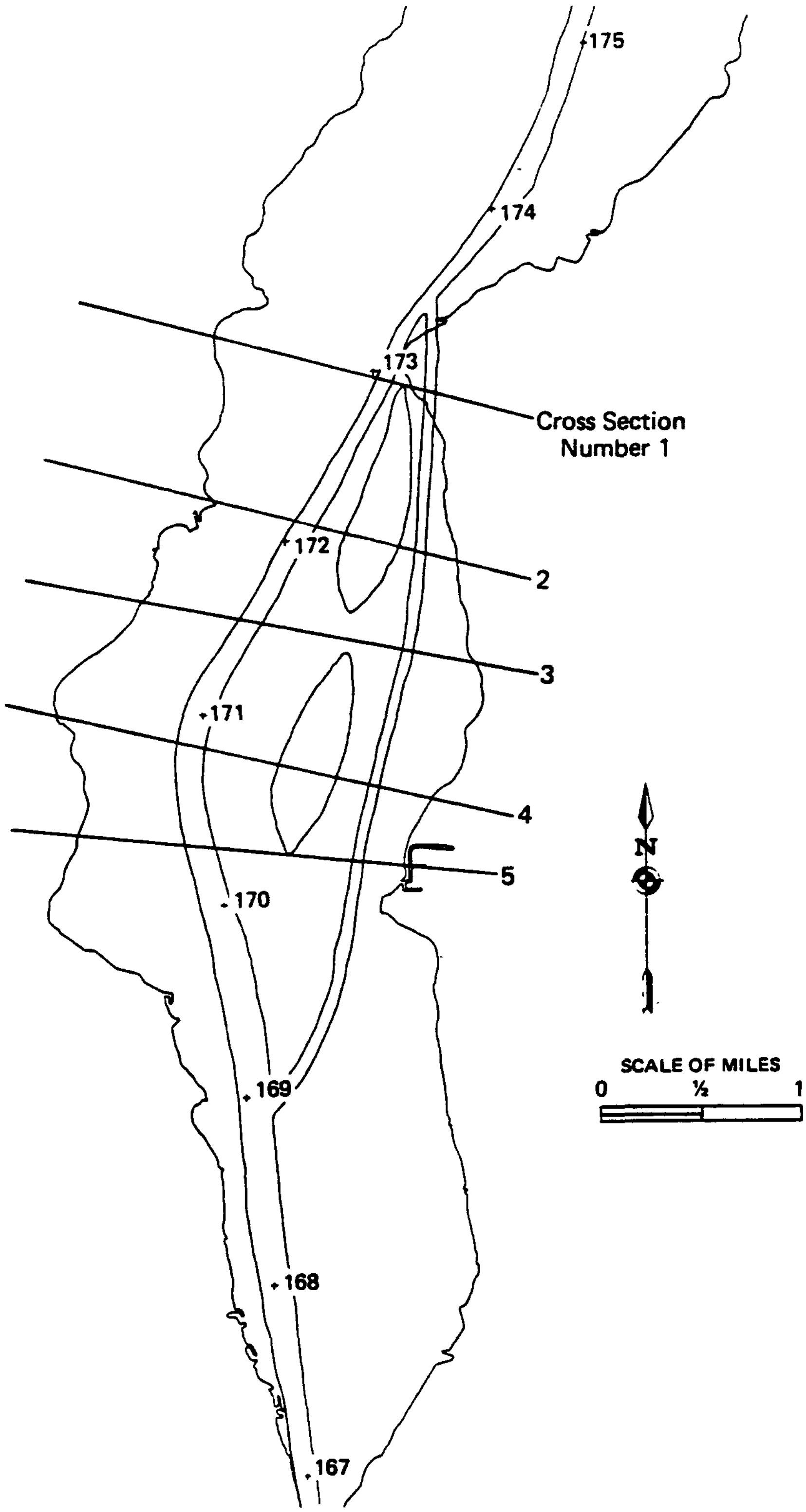

Figure 35. Locations of selected cross sections in Upper Peoria Lake

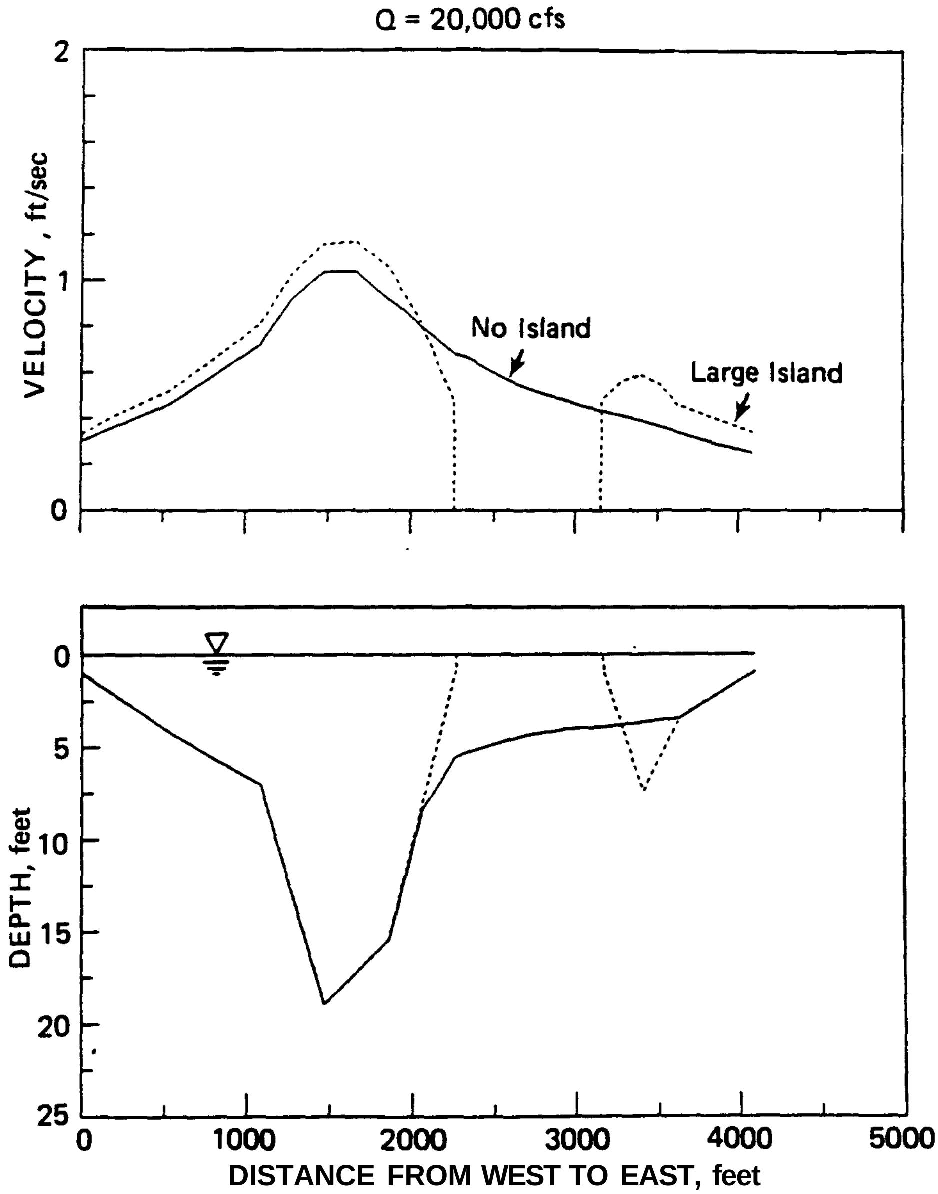

Figure 36. Comparison of velocity distributions at cross section 2 in Lower Peoria Lake for the no island and large island conditions (Q = 20,000 cfs)

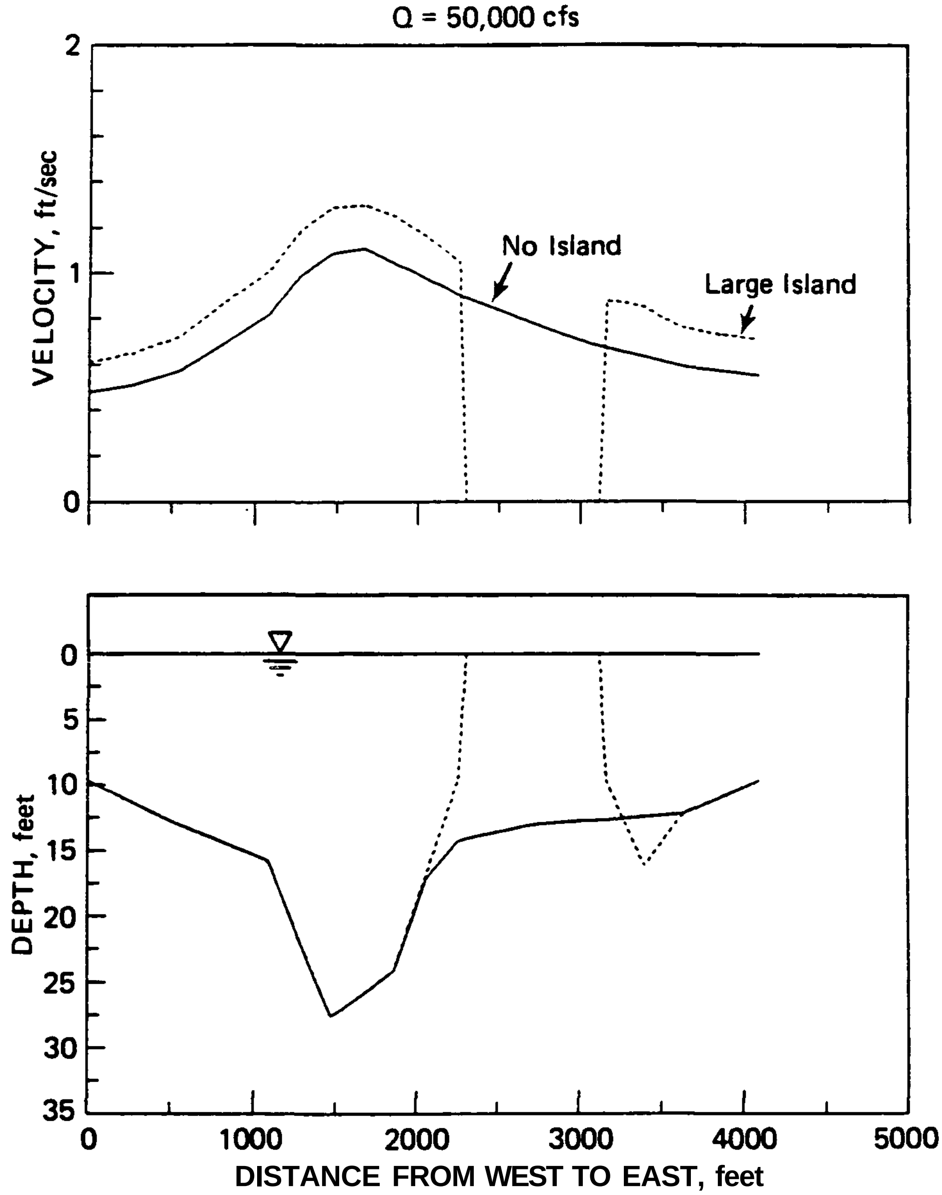

Figure 37. Comparison of velocity distributions at cross section 2 in Lower Peoria Lake for the no island and large island conditions (Q = 50,000 cfs)

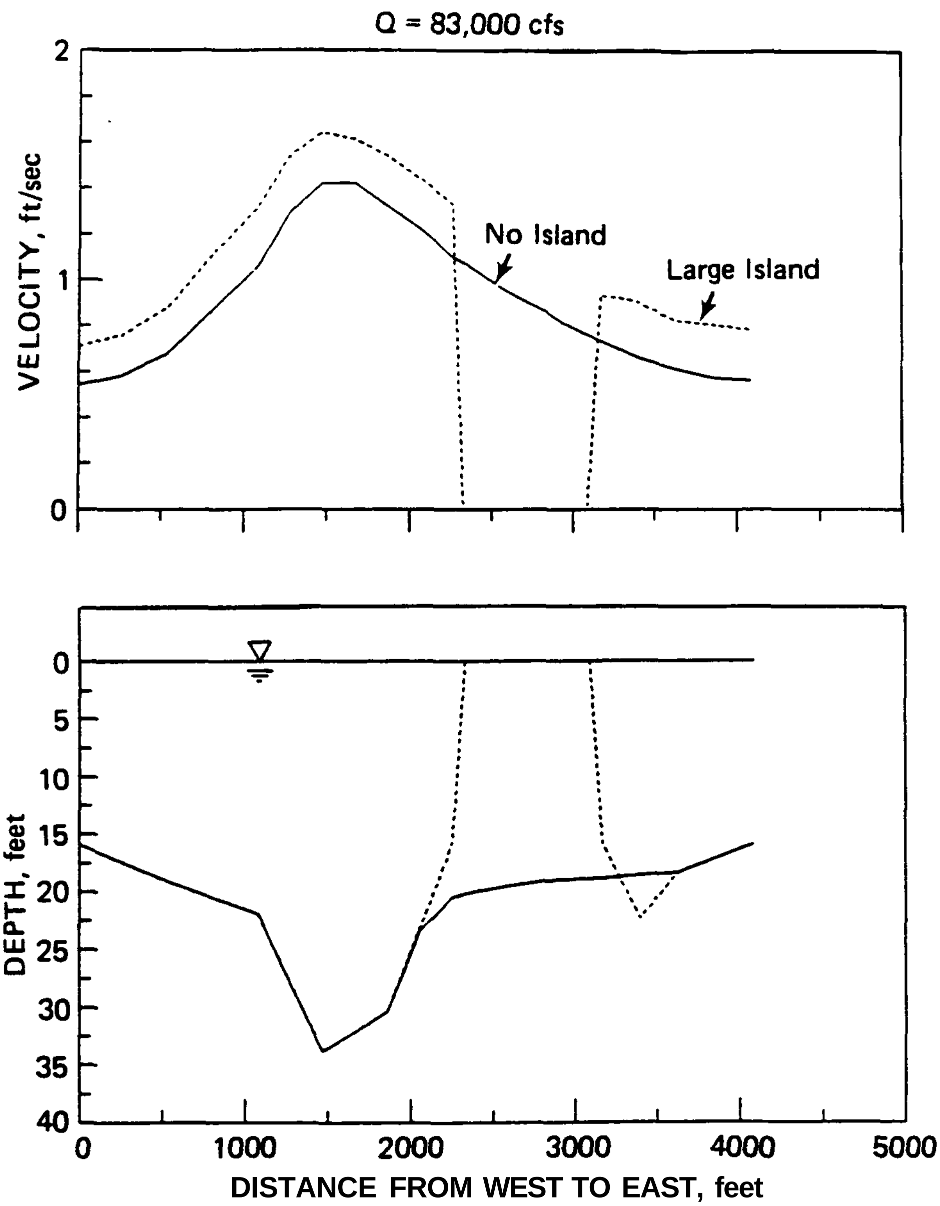

Figure 38. Comparison of velocity distributions at cross section 2 in Lower Peoria Lake for the no island and large island conditions (Q = 83,000 cfs)

Table 5. Maximum Velocities (fps) in the Main Channel and Side Channel for Three Flow Conditions and Different Island Configurations in Lower Peoria Lake

	Main channel			Side channel		
Island configuration	0* = 20.000	0 = 50.000	0 = 83.000	0 = 20.000	0= 50.000	0= 83.000
No island	1.04	1.11	1.42	0.44	0.65	0.70
Small island	1.15	1.35	1.76	0.56	0.69	0.99
Large island	1.17	1.30	1.64	0.59	0.89	0.93
Rotated island	1.27	1.43	1.80	0.52	0.70	0.76
Two islands	1.27	1.43	1.80	0.51	0.70	0.76

*Q in cfs

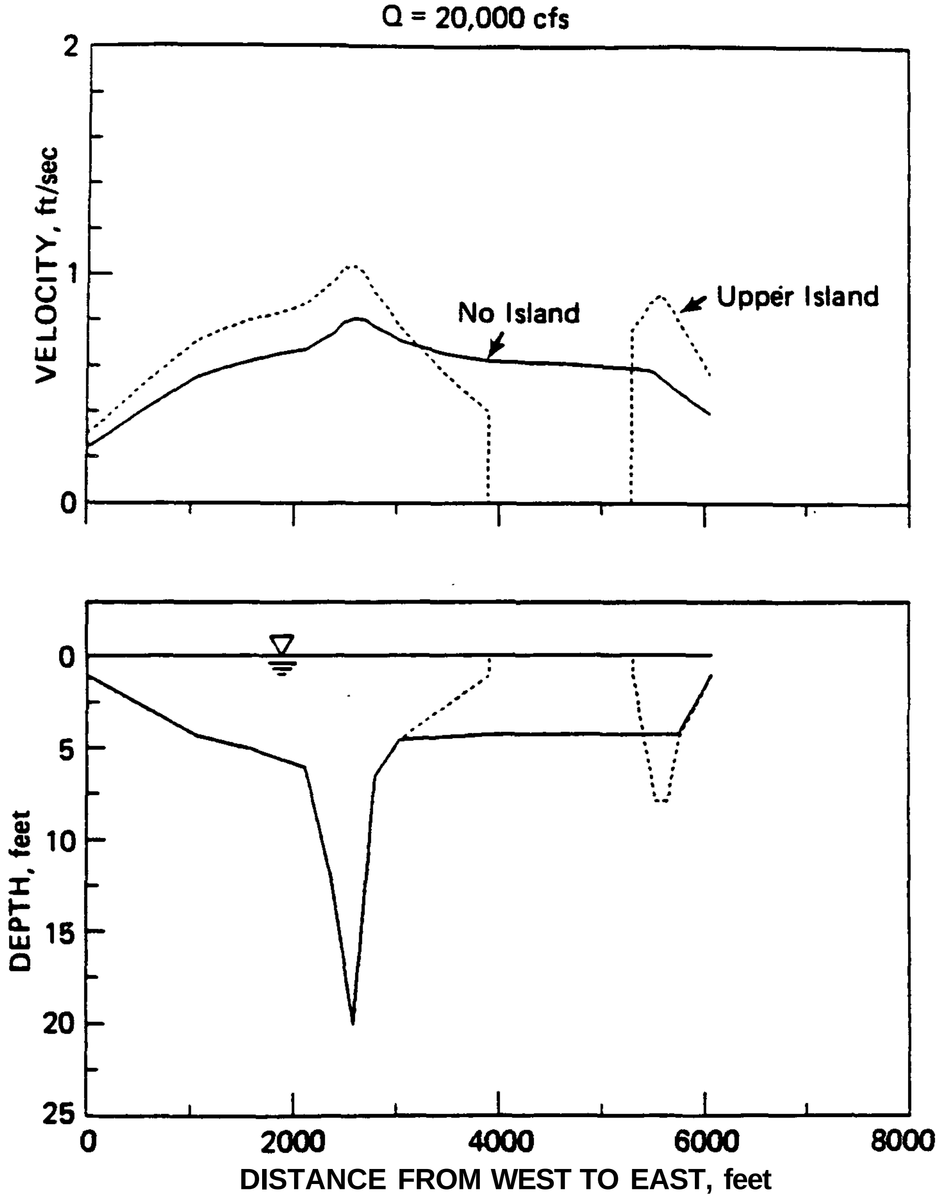

Figure 39. Comparison of velocity distributions at cross section 2 in Upper Peoria Lake for the no island and upper island conditions (Q = 20,000 cfs)

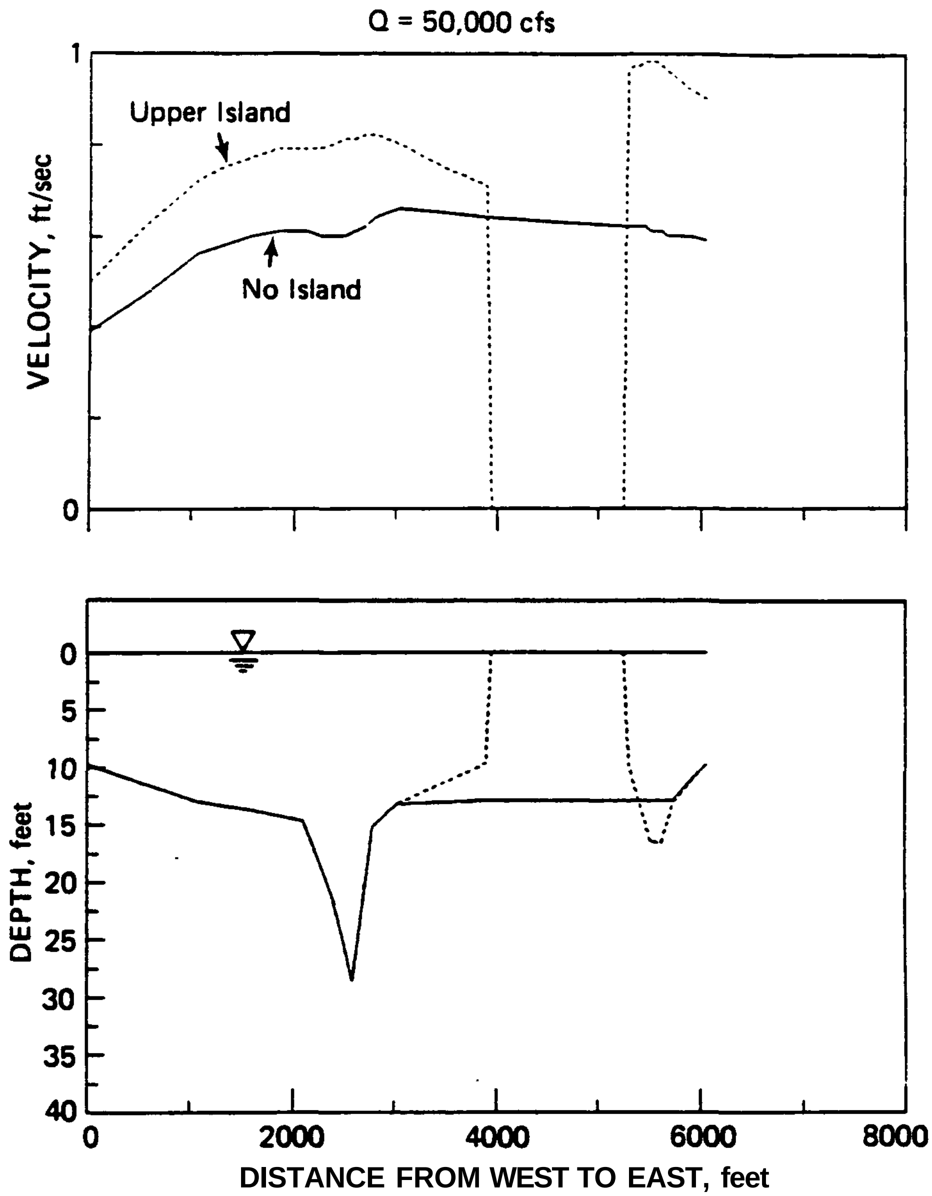

Figure 40. Comparison of velocity distributions at cross section 2 in Upper Peoria Lake for the no island and upper island conditions (Q = 50,000 cfs)

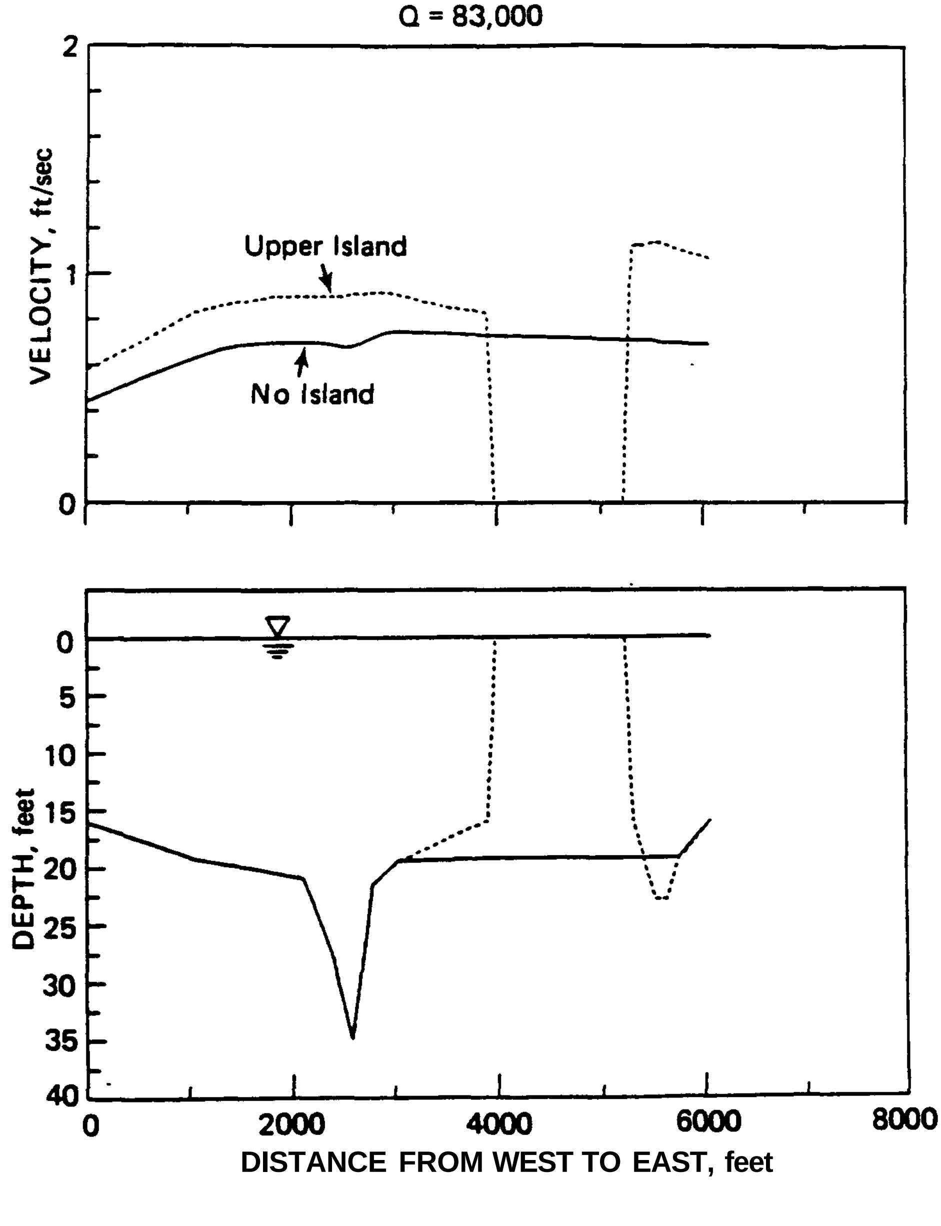

Figure 41. Comparison of velocity distributions at cross section 2 in Upper Peoria Lake for the no island and upper island conditions (Q = 83,000 cfs)

Table 6. Maximum Velocities (fps) in the Main Channel and Side Channel for Three Flow Conditions and Different Island Configurations in Upper Peoria Lake

	Main channel			Side channel		
Island configuration	0* = 20.000	0 = 50.000	0 = 83.000	0 = 20.000	0 = 50.000	0 = 83.000
No island	0.81	0.66	0.75	0.52	0.61	0.70
Upper island	1.04	0.82	0.92	0.91	0.98	1.14
Two islands	1.02	0.81	0.92	0.98	1.01	1.18

*Q in cfs

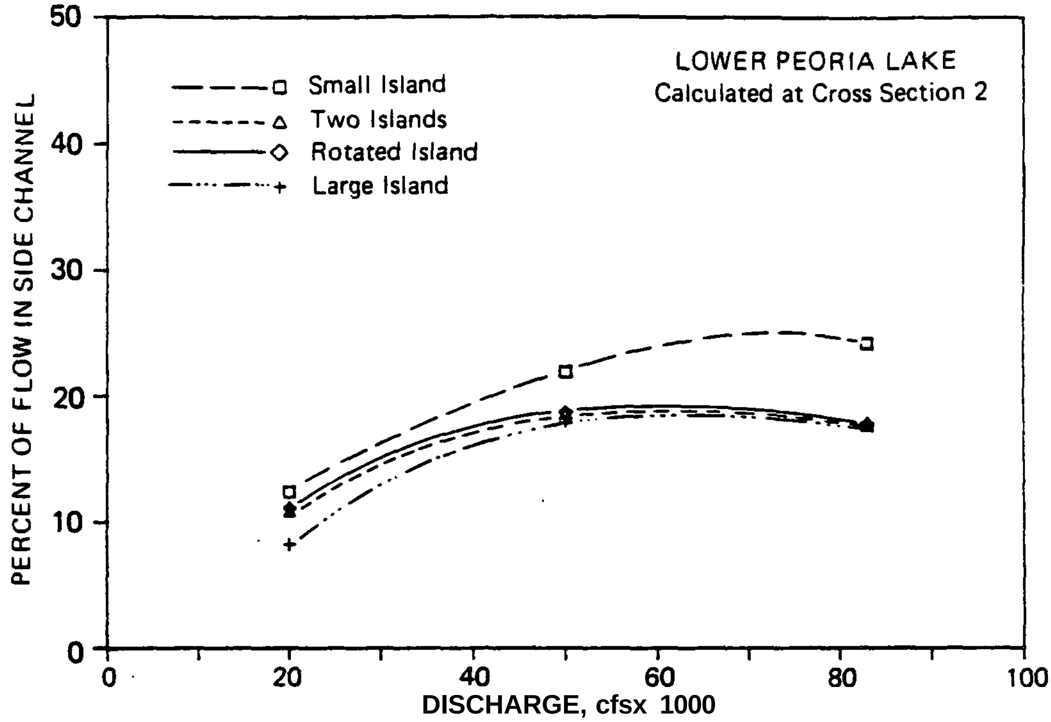

Figure 42. Division of flow between the main channel and side channel in Lower Peoria Lake

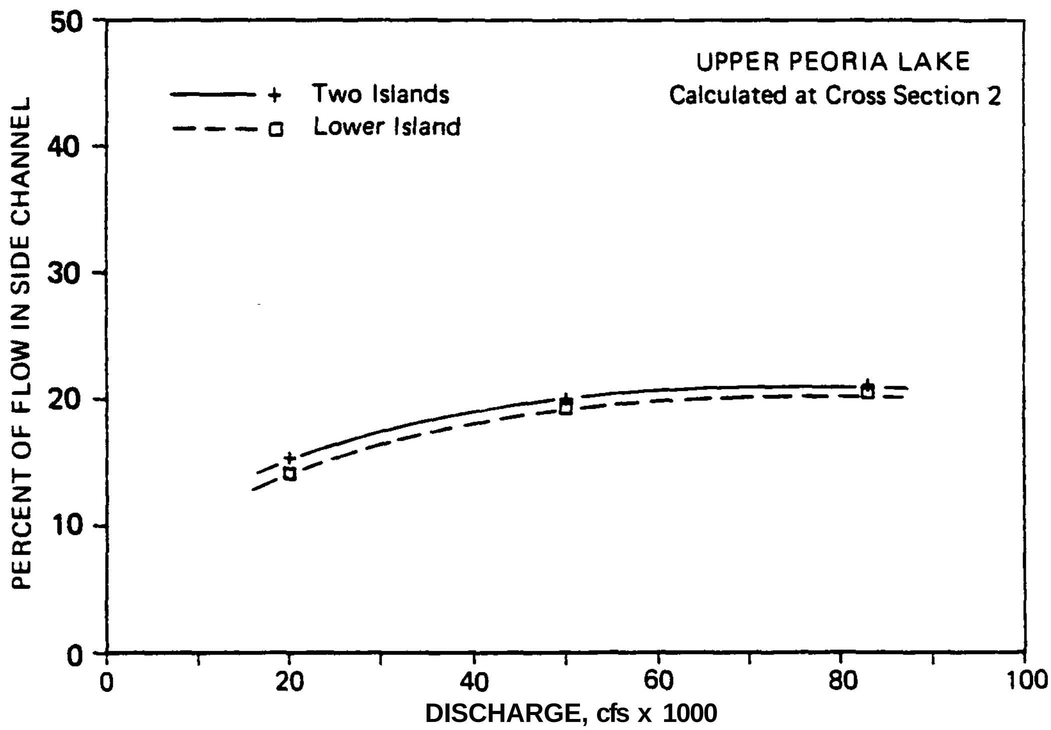

Figure 43. Division of flow between the main channel and side channel in Upper Peoria Lake

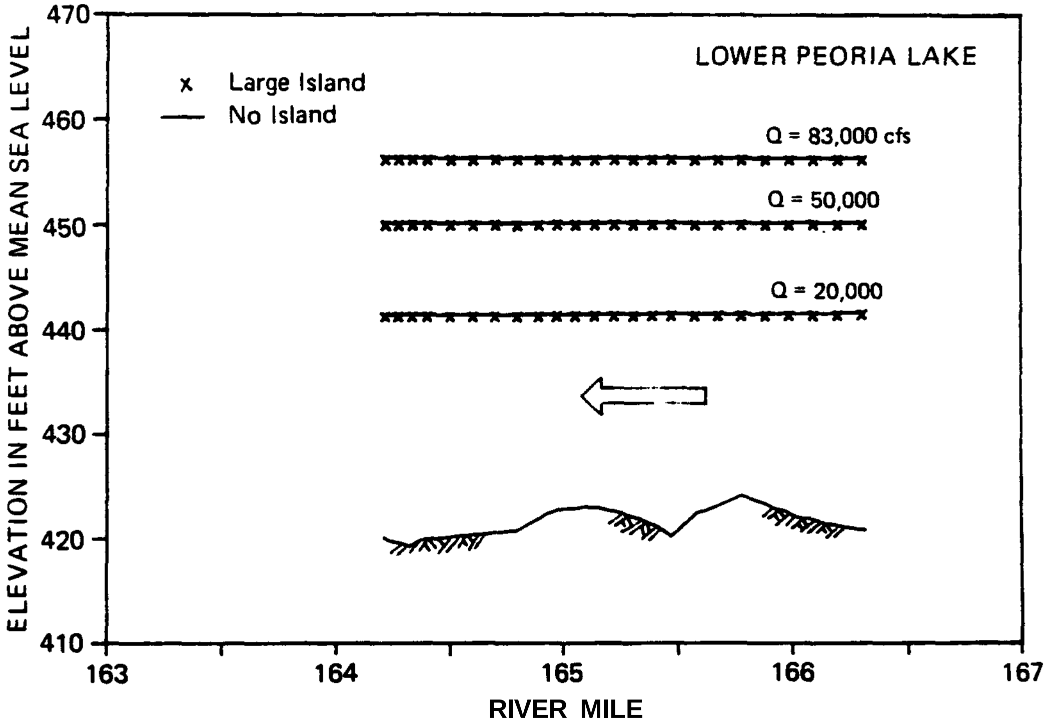

Figure 44. Comparison of water surface elevations in Lower Peoria Lake based on TABS-2 simulation

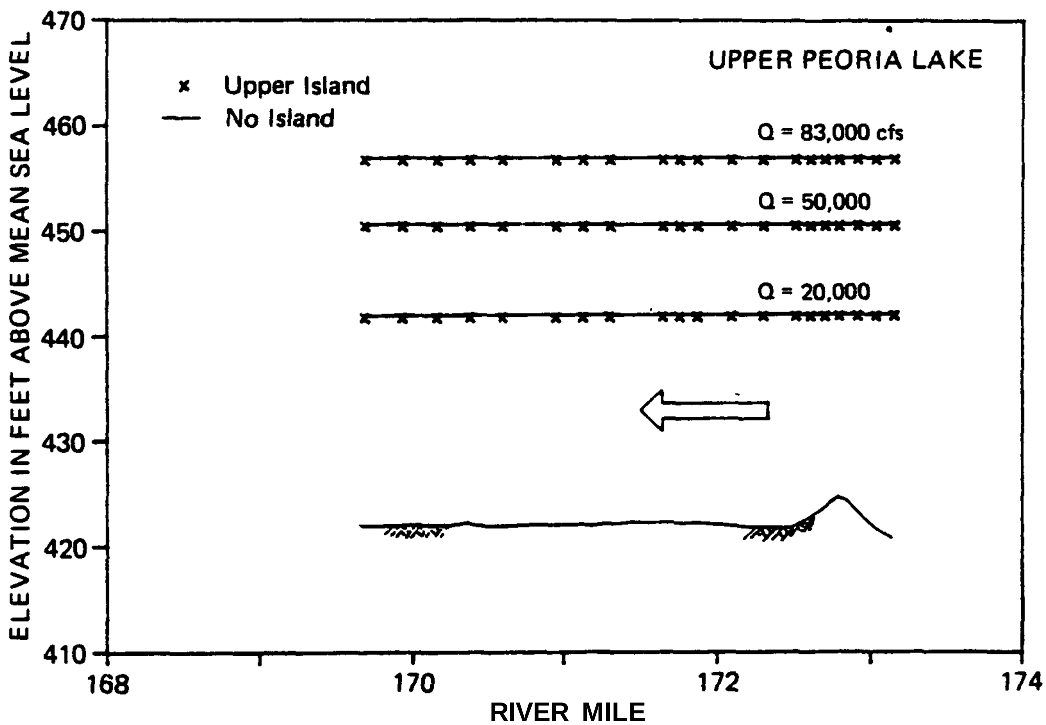

Figure 45. Comparison of water surface elevations in Upper Peoria Lake based on TABS-2 simulation

RECOMMENDATIONS

The hydraulic investigation of selective dredging and construction of islands in Peoria Lake did not reveal any major problems that would make the proposal infeasible. As a matter of fact, the idea is genuinely the best method available for rehabilitating part of Peoria Lake, and implementing it would make large areas of the lake more biologically productive and easily accessible for recreation and other purposes. At the same time, however, this should not be taken as the solution for the entire problem in the lake, and other alternatives for rehabilitating the lake should be pursued. Furthermore, for financial and technical reasons, it is likely that only one island could be built in the near future. With the above points in mind, the recommendations of the study are as follows.

1. Select the location for dredging and constructing one island. On the basis of hydraulics and other important considerations, two sites (one in Lower Peoria Lake and the other in Upper Peoria Lake) have been selected as the best locations for building islands. From the hydraulic study it is difficult to choose one location over the other; therefore a recommendation on which site is preferable is not made in this report. Further discussion and comments from both the general public and state and federal agencies should be considered before making the final selection of the site.

2. Prepare the necessary environmental impact assessment studies and documents for the specific site as quickly as possible. It is almost certain that an environmental impact statement will be required for the project, and some additional studies might also be needed. All the federal and state agencies should outline the required environmental concerns, and a report should be prepared as soon as possible to answer those concerns. It should be emphasized, however, that the first island should be treated as a demonstration project The monitoring program that will accompany the project will provide the data and information needed to address most of the questions and concerns.

3. Prepare a comprehensive environmental monitoring program that will be conducted during and after construction of the island. This is a necessary component of the project since any environmental impact assessment report will not be able to answer all the questions that are likely to be asked about the project Furthermore, it is hoped that the construction of one island will be just the beginning of the process of rehabilitating the lake, and that process will require building more islands in the future. Therefore it is important to obtain and analyze all the data and information that can be gathered from this project

4. Get cooperation and support for the project from local groups and state and federal agencies. This project is an important step in the rehabilitation of Peoria Lake. All aspects of the project including all the known benefits and negative impacts should be discussed among the groups and agencies that are interested in the future of the Illinois River in general and Peoria Lake in particular. This cooperation is extremely important because it affects the funding, cost and eventually the actual implementation of the project

5. Build one island as a demonstration project and initiate proposals to build more islands in the future. As discussed earlier in the report one island will not be sufficient to rehabilitate the lake and create the desired environment in the lake. A chain of islands in both Upper Peoria Lake and Lower Peoria Lake is needed in the long run. It is clear, however, that financial resources are not available at present to build more than one island. Therefore it is important to use the first island as a demonstration project and make sure that the job is done properly so the chances of obtaining funding for future islands are enhanced.

SUMMARY

Peoria Lake is a large natural lake on a major river and national waterway. The natural processes of erosion and sedimentation and to a large extent the developments in the watershed and the river have significantly increased the sedimentation rate in the lake and reduced its usefulness to the citizens of central Illinois. There has not been any program to manage the lake and deal with the sedimentation problem until the recent efforts to initiate lake rehabilitation and erosion control measures.

The initial study by the Illinois State Water Survey for the U.S. Army Corps of Engineers, Rock Island District (Demissie and Bhowmik, 1985) analyzed the sedimentation problem in the lake and recommended a list of alternative solutions that should be pursued further. Among the solutions recommended were selective dredging and island construction in the lake. These two alternatives were believed to be the best alternatives for dealing with the sediment which has already accumulated in the lake. In a further analysis, the Rock Island District determined that selective dredging and island construction has a benefit/cost ratio of over 4 based on recreational benefits alone, without taking any of the environmental benefits into consideration. Unfortunately the Corps could not pursue the project any further under existing programs, since the project would not provide flood protection, but it recommended that the project be pursued by local groups and state agencies (USACOE, 1987).

Even though selective dredging and island construction was the alternative selected for dealing with the sediment in the lake, detailed studies were needed to investigate the feasibility of constructing islands in Peoria Lake. This project, funded by the Department of Energy and Natural Resources, is one of the initial studies needed as a step toward implementing this concept in Peoria Lake. At the same time, a proposal for selective dredging and island construction in Peoria Lake has been submitted by the state to the Environmental Management Program (EMP) of the Upper Mississippi River System. At present, the response of the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service has been favorable, and the project might be funded under the EMP program. Since only projects designed to rehabilitate habitats for fish and wildlife, and not recreational projects, can qualify for EMP funding, careful analysis and design are needed to get the project funded.

The initial analysis and conceptual design developed under this project specifically revolve around enhancement of the environmental quality of the lake and do not concentrate on recreational benefits. However, any project designed to rehabilitate a lake is bound to increase the recreational opportunities, and thus this outcome is expected for Peoria Lake if some areas are dredged and islands constructed. The major benefits of selective dredging and island construction identified for Peoria Lake include:

- Providing improved and diversified aquatic and riparian habitats
- Serving as dredged material disposal sites for both navigation channel maintenance and selective dredging
- Reducing wind- and navigation-induced resuspension of sediment and turbidity
- Reducing sedimentation rates in the areas where islands are constructed
- Providing more suitable water-based recreational sites in Peoria Lake
- Providing a side channel away from the navigation channel for safe recreational boating

Even though there are recreational benefits, most of the benefits are associated with the improvement in aquatic habitats for fish and wildlife.

The conceptual design developed through this study includes side channels along with the islands to maximize the environmental benefits. With such an arrangement and on the basis of other practical considerations such as availability of sand and gravel for constructing retaining dikes, the best locations for constructing islands were narrowed to two primary locations, one in Lower Peoria Lake and the other in Upper Peoria Lake. Detailed hydraulic analyses using two models show that constructing islands and side channels will increase velocities and slightly decrease water surface elevations in the areas where islands are proposed. However, the increased velocities that might result from the project are not great enough to threaten the stability of the islands. Furthermore, the hydraulic influence of the islands and side channels would be limited to the areas of the lake for which the islands are proposed and would not result in increased water surface elevations farther upstream of the sites. This is primarily due to the cross-sectional size of the lake and to the inclusion of a side channel along with the islands.

The hydraulic analyses performed for this project and the review of information relevant to island construction suggest that island construction in Peoria Lake is feasible and is probably the best rehabilitation project for the lake. Therefore, the recommendations of the study are:

1. Select one of the two locations identified in this report as the location for dredging and island construction.
2. Prepare the necessary environmental impact assessment studies and documents for the selected site as quickly as possible.
3. As part of the environmental impact assessment document, prepare a comprehensive environmental monitoring program for the project
4. Obtain cooperation and support for the project from local groups and state and federal agencies.
5. Build one island as a demonstration project, and initiate proposals to build more islands in the future.

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16. Abstract (Limit: 200 words)

This report summarizes the results of a project designed to conduct the initial hydraulic analyses on the feasibility of building islands from dredged material in Peoria Lake. The study makes recommendations on the type, size, number, and locations of islands to facilitate their construction as a rehabilitation measure for the lake. This is the first time this kind of project has been proposed for an environment where a large river flows through the middle of a lake and the sediment in the lake is primarily silt and clay. Project implementation would require detailed hydraulic and engineering analyses not within the scope of this work.

Antecedent work by the Illinois State Water Survey demonstrated the seriousness of the sedimentation problem in Peoria Lake and identified the creation of islands with selectively dredged sediments as a component of a set of recommended alternatives. Properly designed and located islands are recognized as a way to tremendously enhance the environmental quality of the Peoria Lake and to contribute heavily to its rehabilitation and management.

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