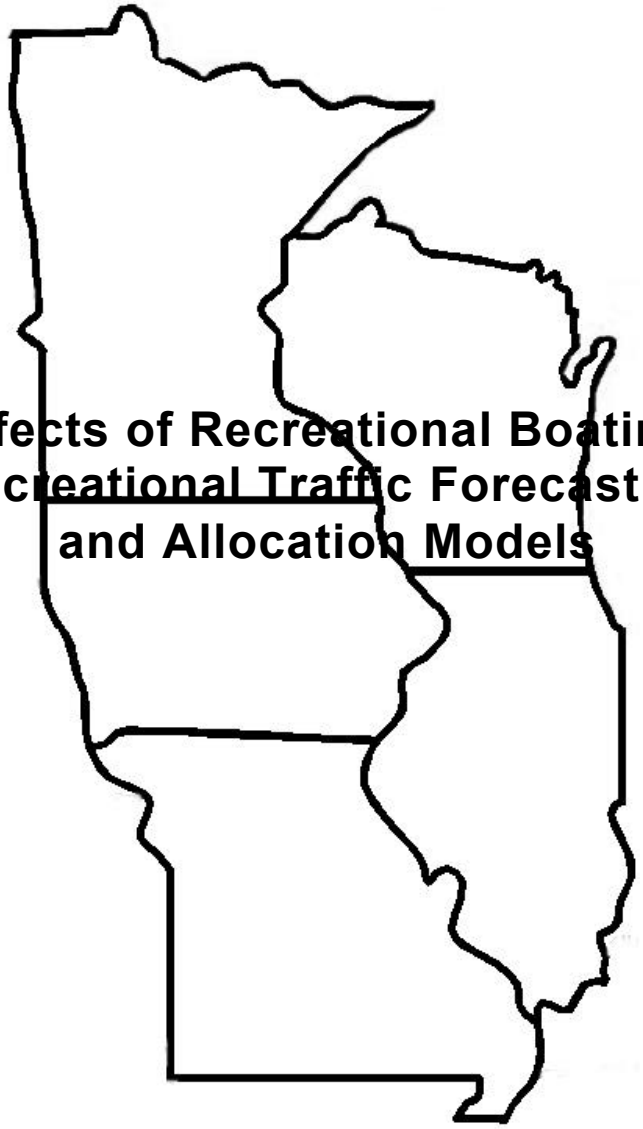
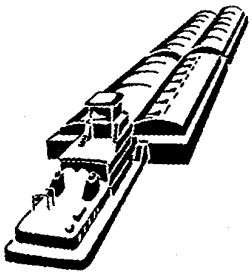
ENV Report 18

Interim Report For The Upper Mississippi River - Illinois Waterway System Navigation Study



Effects of Recreational Boating: Recreational Traffic Forecasting and Allocation Models



July 2000

Rock Island District
St. Louis District
St. Paul District

US Army Corps of Engineers

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Upper Mississippi River - Illinois Waterway
System Navigation Study

ENV Report 18
July 2000

Effects of Recreational Boating: Recreational Traffic Forecasting and Allocation Models

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Interim report

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Preface

The work reported herein was conducted as part of the Upper Mississippi River - Illinois Waterway (UMR-IWW) System Navigation Study. The information generated for this interim effort will be considered as part of the plan formulation process for the System Navigation Study.

The UMR-IWW System Navigation Study is being conducted by the U.S. Army Engineer Districts of Rock Island, St. Louis, and St. Paul under the authority of Section 216 of the Flood Control Act of 1970. Commercial navigation traffic is increasing, and in consideration of existing system lock constraints, will result in traffic delays that will continue to grow in the future. The system navigation study scope is to examine the feasibility of navigation improvements to the Upper Mississippi River and Illinois Waterway to reduce delays to commercial navigation traffic. The study will determine the location and appropriate sequencing of potential navigation improvements on the system, prioritizing the improvements for the 50-year planning horizon from 2000 through 2050. The final product of the System Navigation Study is a Feasibility Report which is the decision document for processing to Congress.

This report was written by Mr. Bruce D. Carlson, U.S. Army Engineer District, St. Paul, and Mr. Steven M. Bartell and Ms. Kym Rouse Campbell, The Cadmus Group, Inc., Oak Ridge, TN. The authors appreciate the many helpful discussions and comments from Mr. Daniel B. Wilcox, U.S. Army Engineer District, St. Paul. Project support was provided by Messrs. Wilcox and Kenneth A. Barr and Richard Fristik, U.S. Army Engineer District, Rock Island. The authors appreciate the helpful comments provided by Mr. Frank Ward, a consultant who performed an independent technical review of an earlier draft of this report. Mr. Ward is an economist in the Department of Agricultural Economics and Agricultural Business, New Mexico State University, Las Cruces, NM. Thanks to Ms. Cindy Woodard, Cadmus Group, for providing clerical and editorial support.

Mr. Robert C. Gunkel, Jr., Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC), was responsible for coordinating the necessary activities leading to publication. Dr. John W. Keeley was Acting Director, EL, ERDC.

At the time of publication of this report, Director of ERDC was Dr. James R. Houston, and Commander was COL Robin R. Cababa, EN.

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Summary

The Upper Mississippi River-Illinois Waterway (UMR-IWW) System Navigation Study includes ecological risk assessments of the potential effects of projected increases in commercial navigation traffic on fish, freshwater mussels, and submerged aquatic plants. In addition, the potential for bank erosion resulting from future commercial traffic is being evaluated as part of the Navigation Study. The period of interest for the assessments of effects resulting from increasing commercial traffic is from 2000 to 2050.

The UMR-IWW System is also subject to significant use by the recreational boating public, and this use is expected to increase during the same period. Some observed patterns of recreational boating suggest that its possible effects on the ecological resources in the UMR-IWW System should also be assessed. The assessment of recreational traffic effects can provide an additional context for evaluating the significance of potential ecological risks posed by commercial traffic in the UMR-IWW System.

This report describes recreational traffic forecasting and allocation models that have been developed to estimate the future changes in recreational boating on the river system. The forecasting model calculates recreational boat trips for each pool for the years 2000, 2010, 2020, 2030, 2040, and 2050. The allocation model calculates trips per day of seven recreational vessel types (sailboat, fishing boat, pontoon boat, jet ski, medium powerboat, large cruiser, and houseboat) for each pool of the UMR-IWW System for the years 2000, 2010, 2020, 2030, 2040, and 2050. Traffic forecasts developed for each pool are allocated to a particular vessel class, month, and day using available studies.

Methods of numerical sensitivity and uncertainty analyses were used to examine the possible variation in the allocation model estimates of recreational boating activity. The allocation model was necessarily developed using incomplete and imprecise data that describe present and project future spatial and temporal patterns of recreational boating on the UMR-IWW System. The uncertainties associated with each model input parameter were evaluated by defining each input parameter as a statistical distribution and performing 1,000 model simulations using values selected at random from their respective distributions. The analyses were performed, as an example, for the projected number of medium powerboats in Pool 13 on June 1 (weekday) and June 3

(weekend day) in the year 2000. The results of these simulations provide an estimate of the precision of the model calculations. Analysis of the 1,000 simulations performed for each selected day identified which input parameters (trips/pool/year, trips/pool/vessel class/year, trips/pool/vessel class/month, and trips/pool/vessel class/day) contributed most to imprecision in the allocation model results. These parameters would be the focus of future data collection to improve the reliability of the recreational traffic allocation model.

The recreational traffic allocation model will be linked to a Navigated Areas Geographic Information System (GIS) Database, developed to describe the within-pool distribution of vessel types, to estimate the ecological risks associated with recreational traffic. Physical forces associated with recreational vessel types will be calculated using models and available studies in order to estimate the effects on the ecological resources of the UMR-IWW System. The ecological effects associated with the increase in recreational traffic from the years 2000 to 2050 will be presented in a second report. In addition to the ecological risk assessment methodology, the second report will include descriptions of the methodology developed to quantify the physical forces associated with recreational traffic and a description of the linkage developed between the recreational traffic allocation model and the Navigated Areas GIS Database.

1 Introduction

The Mississippi River is an integral part of American heritage, both as a unique resource and as the best example of a multipurpose river in the United States. The Mississippi River drainage basin is nearly 4 million square kilometers and is one of the largest and most productive ecosystems in the world (Holland-Bartels, Littlejohn, and Huston 1990). The river above the confluence of the Ohio River is commonly called the Upper Mississippi River (UMR) (Figure 1) and includes nearly 500,000 km^2 of watershed (Holland-Bartels, Littlejohn, and Huston 1990). The UMR, including the Illinois Waterway (IWW) (Figure 1), is designated both a nationally significant ecosystem and a nationally significant navigation system, the only inland river in the United States to have such a designation. Many national wildlife refuges exist along the river corridor. The Mississippi Flyway is the migration corridor for 40 percent of North America's waterfowl and shorebirds, as well as an important flyway for raptors and neotropical songbirds. A total of 50 species of freshwater mussels have been recorded in the river system. In addition, the Mississippi River System is noteworthy among the world's large temperate rivers because it supports an unusually large number of fish species; historically, at least 150 species of fish have been reported in the UMR (Gutreuter 1997).

The history of navigation on the UMR-IWW System goes back to the 1820s, when Congress authorized navigation improvement measures by the U.S. Army Corps of Engineers (USACE), such as the removal of snags and other obstructions in several locations of the Mississippi River and construction of a canal connecting Lake Michigan to the IWW (Fremling and Claflin 1984). Several navigation improvement projects, including excavating rocks, closing off sloughs, and constructing the 4.5-ft (1.4-m) and the 6-ft (1.8-m) navigation channels, continued throughout the early 1900s (Fremling and Claflin 1984). Projects creating the current 9-ft (2.7-m) navigation channel were authorized in the 1930s, and most were completed by 1940 by the USACE (Fremling and Claflin 1984). Twenty-nine locks and dams on the Mississippi and eight on the Illinois replaced rapids and falls with a stairway of water or a series of terraced pools for commercial and recreational traffic (Figure 1). Habitats in a typical pool include a braided channel, a lotic area at the head of the pool, and a lentic environment above the impounding lock and dam (Van Vooren 1983).

The Navigation Study being performed for the UMR-IWW System consists of several component studies including assessments of the potential effects of

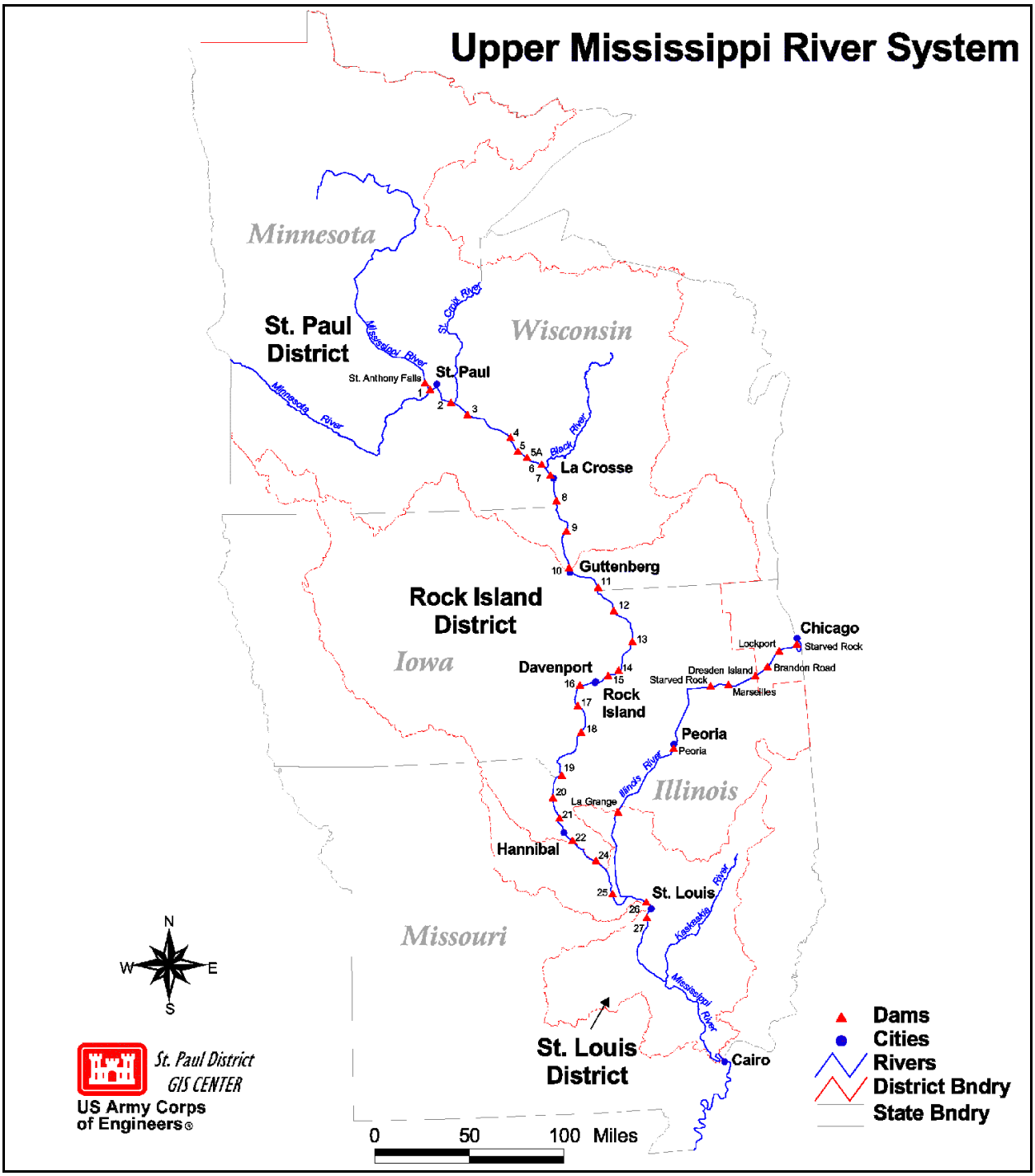

Figure 1. The Upper Mississippi River-Illinois Waterway System (the pool upstream from the dam has the same number or name as the dam)

projected increases in commercial navigation traffic on ecological resources in this large river system. These studies focus on potential impacts on submerged aquatic plants, freshwater mussels, and fish. The Navigation Study is also evaluating the potential for bank erosion resulting from future commercial

traffic. The period of interest for the commercial traffic assessment extends from approximately 2000 through 2050.

The UMR-IWW System also experiences significant use by the recreational boating public, and this use is expected to increase during this same period. Recreational vessels differ from commercial traffic in their spatial and temporal patterns of river use, vessel speeds, and total trips. Some observed patterns of boating (e.g., high speeds near shore or in backwater areas) suggest that possible impacts of recreational traffic on ecological resources in the UMR-IWW System should also be assessed.

The purpose of this report is (a) to quantitatively characterize in a detailed manner the present recreational boating use of the UMR-IWW System by developing recreational traffic forecasting and allocation models, and (b) to estimate future changes in recreational boating on the river system for the period 2000-2050 by using the models to forecast future recreational traffic. The assessment of recreational traffic can provide an additional context for evaluating the significance of potential environmental risks posed by commercial traffic in the UMR-IWW System.

The objective of developing recreational traffic forecasting and allocation models was to provide estimates of future recreational traffic commensurate in spatial-temporal scale and level of resolution with the projected increases of commercial vessels. Ultimately, the traffic allocation model will estimate, for each recreational category, the number of vessels using different areas within pools on a daily basis. These projections will serve as the basis for a second study that will describe methods for assessing possible ecological impacts associated with recreational boating traffic on the UMR-IWW System and provide a preliminary assessment of these potential risks.

It is important to note that the recreational boating projections in this report are subject to much more uncertainty than the corresponding projections for commercial navigation traffic. Systemwide recreational boating use has been measured only for one boating season and on a broad geographic scale. In contrast, commercial traffic has been documented at the scale of individual lockages for many years. The approach taken in this report was to develop a set of reasonable assumptions based on available information from the many past studies of recreational boating on the UMR-IWW System, supplemented with professional judgment from resource professionals most familiar with these activities.

The resultant models are a conditional forecast of boating traffic, based primarily on projected changes in the study area. While the precision of the estimates is limited, especially at a local geographic scale, the potential usefulness of the models lies in the identification of factors important to recreational boating and subsequent effects on UMR-IWW System ecological resources. Associated sensitivity and uncertainty analyses have been performed to highlight the factors that have the greatest influence on the results of the recreational traffic projection models.

Study Area

Geographically, the study includes the commercially navigable portions of the UMR (north of Cairo, IL), the IWW, the St. Croix River, the Minnesota River, and the Kaskaskia River (Figure 1). The UMR-IWW System contains nearly 2,100 m (1,300 miles) of commercially navigable waters. Also included in the study area are the side channels, sloughs, and lakes associated with these rivers, as well as the land immediately adjacent to them. The rivers are found within the states of Minnesota, Wisconsin, Iowa, Illinois, and Missouri. In addition, seventy-six counties (plus the city of St. Louis) border the study area.

The Recreational Traffic Forecasting Model

Several steps, which are summarized in this report, are involved in the overall approach used to develop the recreational traffic forecasting model. The process starts with highly aggregated data used to estimate the total number of current recreational boat trips in each USACE District of the UMR-IWW System. The model development process continues by disaggregating the annual District number into percentages by pool using available studies. The total number of current trips per pool is then adjusted for the year 2000. Forecasts of annual trips per pool are then calculated based on county population growth projections developed during this study. The forecasting model provides recreation traffic projections for every 10 years (e.g., 2000, 2010, 2020...2050) for each pool of the UMR-IWW System. Traffic projections at finer temporal resolution (i.e., yearly) would require interpolation between the decadal projections produced by the current version of the model. The forecasts of annual trips per pool are the critical link and input to the traffic allocation model.

The accuracy and precision of the recreational traffic forecasting model depend on the quality of the available traffic data and assumptions involved in interpolating and extrapolating these data. The implications of these uncertainties for the forecasting model predictions are discussed in Chapter 4.

The Recreational Traffic Allocation Model

The approach used to develop the recreational traffic allocation model involved several steps. The process started with forecasts of the total number of trips in each pool of the UMR-IWW System for the years 2000, 2010, 2020, 2030, 2040, and 2050. The model development process continued by successively disaggregating the annual pool numbers to allocations by vessel category, to vessels per month, and finally to vessels per day for each of the seven vessel classes. Within-pool daily use projections for each vessel class will be developed by linking the traffic allocation model to the Navigated Areas Geographic Information System (GIS) Database. The traffic allocation model results will be used in the eventual ecological risk assessment.

As with the recreational traffic forecasting model, developing the allocation model involved assumptions, sparse data, and associated uncertainties. Therefore, the potential effects of these uncertainties on the predictions of the allocation model were quantitatively evaluated using methods of numerical sensitivity and uncertainty analysis for selected pools, dates, and vessel types.

Recreational Fleet Characteristics

Assessing the potential ecological impacts associated with recreational traffic requires characterization of several physical features of different vessel classes. For example, statistical distributions describing boat lengths, propeller diameters, and typical traveling speeds of different vessel classes are needed to translate vessel movement to physical forces (e.g., river current velocities, wake waves, shear stresses) that might adversely impact submerged aquatic plants, mussels, and fish in the UMR-IWW System. In addition, trends in fleet characteristics (e.g., increasing average boat size) that can be established or anticipated for the project period might prove important in assessing ecological risks posed by recreational traffic on the system.

Navigated Areas GIS Database

To assess the potential ecological effects associated with recreational traffic, results of the allocation model simulations will be used to develop GIS-generated maps illustrating the spatial distribution and estimated intensity of future recreational boating traffic in the UMR-IWW System. In addition, a set of GIS coverages will be developed on a pool-by-pool basis defining the magnitudes and spatial extent of hydraulic disturbances produced by recreational vessels. These hydraulic disturbances will be used to assess the risks posed by recreational vessels to submerged aquatic plants, freshwater mussels, fish, and bank erosion in a manner that parallels the assessment of similar risks posed by projected increases in commercial traffic.

2 The Recreational Traffic Forecasting Model: Data, Methods, and Results

The recreational traffic forecasting model, the data sources used to develop the model, and the overall model development methodology are described in this chapter. In addition, forecasts of recreational traffic for the years 2000, 2010, 2020, 2030, 2040, and 2050 for each pool of the UMR-IWW System are presented. A schematic outline of the overall recreational traffic forecasting model is presented in Figure 2.

Data Sources Used to Develop the Recreational Traffic Forecasting Model

This section describes the various studies, including their strengths and limitations, used to develop the recreational traffic forecasting model. Ideally, studies could be implemented to perform a detailed statistical sampling of recreational use patterns on the river system; however, additional studies are beyond the intent, scope, and resources available for this recreational traffic study. At the same time, efforts continue to identify additional sources of existing data that might have been overlooked during model development.

Economic impact of recreation on the UMR-IWW System Study

The Economic Impact of Recreation on the UMR-IWW System Study (REC-EC Study) is the first of its kind undertaken for the UMR-IWW System that produced basinwide estimates of the total number of recreation visitors, the activities they engaged in, the amount of money they spent on recreation, and the patterns evident in their spending (Carlson et al. 1995). It is the only study that measures systemwide boating use in a statistically valid way. These systemwide use estimates establish the baseline (current condition) for recreational use in the present modeling effort.

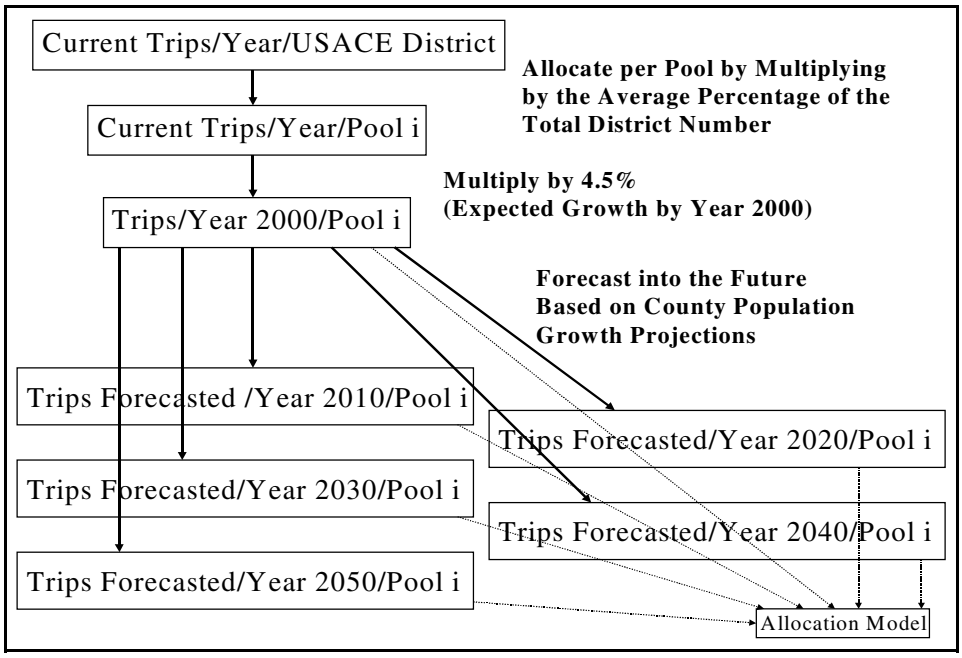

Figure 2. A schematic outline of the recreational traffic forecasting model

The study measured recreational use in four UMR-IWW System regions. Three of the four regions conform to the USACE District boundaries: Region 1, in the St. Paul District, covers the Mississippi River from River Miles 614 to 857.6, plus the Black, St. Croix, and Minnesota Rivers; Region 2, in the Rock Island District, covers the Mississippi River between River Miles 300 and 614; and Region 3, in the St. Louis District, covers the Mississippi River from River Mile 300 south to Cairo (River Mile 0), plus the Kaskaskia River. Region 4 (portions of which fall under the jurisdiction of the Rock Island and St. Louis Districts) covers the IWW from Lockport, IL, to the confluence of the Illinois and Mississippi Rivers. The study was directed by the St. Paul District, and data were collected between 1989 and 1991 (Carlson et al. 1995).

Three separate but related surveys were conducted to collect the data. The surveys measured recreational use originating from developed sites along the river (over 600 sites), marina slips (18,000 slips), and permitted boat docks (2,800 docks). Data collection for developed sites and overlooks along the river resulted in 1,316 completed interviews and was completed in November 1990. Telephone surveys measuring the use of permitted boat docks and marina slips were both completed in 1991. These telephone surveys used panels of 150 households who were contacted up to 10 times throughout the survey year.

Carlson et al. (1995) estimated that over 12 million daily visits by recreationists took place during the study year. Boating was the most popular activity, with more than half of all visitors boating (6.9 million boaters). These visits accounted for approximately 2.6 million boat trips during the study year. Boat trips were measured at the point of access, so boating patterns within and

between pools are not available within the data. Other details about the boating trips, such as trip length and amount of time active on the water, were also beyond the scope of the study. In addition, the estimates represent only one point in time, so trends cannot be assessed within the data set. However, a number of checks on the study led to the conclusion that the results provided a reasonably accurate representation of recreational activity during the study year. The checks included comparisons made with two other studies that measured boating use in parts of the UMR-IWW System during the same period. A study conducted in 1989–1990 estimated boating trips from Wisconsin that amounted to 16.4 percent of the UMR-IWW System estimate (Penaloza 1991). In addition, a Twin Cities study conducted in 1991 estimated boating trips from the head of navigation in the UMR to Pool 5 that amounted to 18.8 percent of the UMR-IWW System estimate (Carlson et al. 1995).

Great River Environmental Action Team Studies I, II, and III (UMR Pools 1-27)

The Great River Environmental Action Team (GREAT) studies contain boating estimates by pool for all of the UMR-IWW System stretches in the study area (GREAT 1980a, 1980b, 1981). The GREATs were formed to develop a river management plan for the Mississippi River, extending from the confluence of the Ohio River to the beginning of navigable waters at Minneapolis, MN (Jackson et al. 1984). GREAT I was responsible for the reaches of the Mississippi River from St. Paul-Minneapolis to Guttenberg, IA; GREAT II was responsible for the reaches of the Mississippi River from Guttenberg to Saverton, MO; and GREAT III was responsible for river studies from Saverton to the Ohio River at Cairo (Jackson et al. 1984). Boating estimates were produced for the study base years as well as for projected future years; the base year numbers are presumed to be the most reliable. While these estimates are the result of a large and relatively sophisticated planning effort, the data and methods used to create the estimates have been lost. Additionally, the numbers are becoming dated, although the extent of recreational boat distributions changing through time is unknown.

Recreational Boating Study of the St. Paul District Pools (UMR Pools 1-10)

This study is performed every 2 years by the Minnesota-Wisconsin Boundary Area Commission (MWBAC), funded by the Recreation Work Group of the River Resources Forum. It is the only documented study measuring use pool by pool (Macbeth 1996). The results show strong consistency across years. Only 1993, a year with extreme flooding, shows a dramatically different distribution among pools (less use downstream).

The data gathered by the MWBAC are the best-documented data at the pool level. However, several aspects of the study design do not fully match the requirements of this modeling effort and were taken into account in determining the pool-use percentages for the St. Paul District. The primary limitation is due to physical constraints that prohibit photographing boats in the backwater areas

and in Lake Pepin (Pool 4). The river is too wide in these areas for the procedure to be effective. Other sources consulted in an attempt to account for these boaters included a study conducted in Pools 7 and 8 by the U.S. Army Engineer Waterways Experiment Station (WES) (Vogel, Titre, and Chilman 1996), which compared main channel and backwater use and surveyed river managers familiar with Pools 1 through 10. The WES study of Pools 7 and 8 was also funded by the Recreation Work Group of the River Resources Forum.

Natural Resource Monitoring System (UMR Pools 1-10)

The USACE annually reports the number of boaters for each pool in the St. Paul District as part of the Natural Resource Monitoring System (NRMS) (U.S. Army Engineer District (USAED), St. Paul, 1995). While these numbers have been accepted institutionally, knowledge of their origin has been lost. They are updated annually based on projections prepared in the GREAT I study. Since the update figure is a constant percentage increase, the proportions among pools remains the same through time. While the source of these figures is uncertain, they have been included in the analysis for comparison.

Minnesota Department of Natural Resources Origin-Destination Study (UMR Pools 1-5)

This study was conducted by the Minnesota Department of Natural Resources (MNDNR) in 1993 (Kelly 1993). The effort was a pilot project intended to build toward a mathematical origin-destination model similar to the lake-based models already developed by the state. The applicability to the present study is limited by the number of pools covered. Data from this study were used in a way that made them comparable to the other studies for Pools 1-5.

Current Annual Use by Pool

The first step in developing the recreational traffic forecasting model consisted of using the systemwide and District-wide data to estimate a current total annual use on a pool-by-pool basis for the UMR-IWW System (Figure 2). No systemwide studies measuring boating use at the pool level have been conducted. Such a study would be very expensive and is well beyond the current available resources of interested agencies.

Distributing use among pools was based on data from studies presented in the previous section and ultimately relied on expert opinion. The estimated proportion of use in each pool (by District) is shown for each data source in Table 1. Examination of Table 1 shows that it is evident that the use estimates by pool vary by source and that not all sources have information for all pools. All pool-use figures have been computed as a percentage of their respective regional total for consistency in presentation and application. The estimates or average percentages that are considered the most reasonable and that are used in the forecasting model are listed in Table 2. The methods and considerations used to develop these percentages are discussed in the following paragraphs.

Table 1
Recreational Boating Traffic Use Percentages by Pool for the UMR-IWW System From Various Studies

Pool	MWBAC Rec. Boating Study, 1989 (Macbeth 1996)	MWBAC Rec. Boating Study, 1991 (Macbeth 1996)	MWBAC Rec. Boating Study, 1993 (Macbeth 1995)	MWBAC Rec. Boating Study, 1995 (Macbeth 1996)	REC-EC Site/Slip Distribution (Carlson et al. 1995)	GREAT Studies Base Year (GREAT 1980a)	NRMS (USAED, St. Paul 1995)	MNDNR Org/Dest (Kelly 1993)
UMR-St. Paul District								
U/L SAF	2.30	2.56	1.96	1.4	0.7	1.98	0.39t	0.80
1	0.23	0.34	0.22	0.2	-	1.57	0.76t	13.22 (Combined)
2	4.30	3.45	4.22	4.0	5.6	1.45	7.89	
3	38.94	40.70	50.20	40.4	18.7	11.35	17.67	22.48
4	9.02	10.08	9.28	10.7	19.5	18.48	15.31t	19.70
5	3.24	3.18	2.51	3.6	4.0	5.56	4.11	3.79
5A	3.19	3.43	3.07	3.3	2.7	6.97	6.12	-
6	4.46	3.53	2.75	3.9	3.6	17.64	8.44	-
7	4.56	3.74	2.47	3.6	4.8	7.82	8.18t	-
8	10.54	11.06	9.42	10.9	12.7	8.55	13.14	-
9	7.45	6.56	5.05	6.0	10.4	10.83	8.79	-
10	11.76	11.36	8.85	12.0	17.3	7.79	9.19	-

(Sheet 1 of 3)

Table 1 (Continued)

Pool	MWBAC Rec. Boating Study, 1989 (Macbeth 1996)	MWBAC Rec. Boating Study, 1991 (Macbeth 1996)	MWBAC Rec. Boating Study, 1993 (Macbeth 1995)	MWBAC Rec. Boating Study, 1995 (Macbeth 1996)	REC-EC Site/Slip Distribution (Carlson et al. 1995)	GREAT Studies Base Year (USACE 1980a)	NRMS (USACE 1995)	MNDNR Org/Dest (Kelly 1993)
UMR-Rock Island District								
11	-	-	-	-	9.2	6.61	-	-
12	-	-	-	-	13.5	7.13	-	-
13	-	-	-	-	12.5	8.18	-	-
14	-	-	-	-	11.9	10.01	-	-
15	-	-	-	-	7.3	10.36	-	-
16	-	-	-	-	10.1	9.91	-	-
17	-	-	-	-	4.8	5.32	-	-
18	-	-	-	-	8.6	6.74	-	-
19	-	-	-	-	10.6	14.33	-	-
20	-	-	-	-	1.9	1.54	-	-
21	-	-	-	-	7.2	12.35	-	-
22	-	-	-	-	2.5	7.52	-	-

(Sheet 2 of 3)

Table 1 (Concluded)

Pool	MWBAC Rec. Boating Study, 1989 (Macbeth 1996)	MWBAC Rec. Boating Study, 1991 (Macbeth 1996)	MWBAC Rec. Boating Study, 1993 (Macbeth 1995)	MWBAC Rec. Boating Study, 1995 (Macbeth 1996)	REC-EC Site/Slip Distribution (Carlson et al. 1995)	GREAT Studies Base Year (USACE 1980a)	NRMS (USACE 1995)	MNDNR Org/Dest (Kelly 1993)
UMR-St. Louis District								
24	-	-	-	-	12.3	10.37	-	-
25	-	-	-	-	14.0	18.63	-	-
26	-	-	-	-	53.4	57.18	-	-
27	-	-	-	-	0.8	13.82 (combined)	-	-
Open River	-	-	-	-	19.6		-	-
UMR-Rock Island District								
Lockport	-	-	-	-	1.7	-	-	-
Brandon Roads	-	-	-	-	0.0	-	-	-
Dresden Island	-	-	-	-	5.2	-	-	-
Marseilles	-	-	-	-	6.4	-	-	-
Starved Rock	-	-	-	-	10.8	-	-	-
Peoria	-	-	-	-	54.8	-	-	-
LaGrange	-	-	-	-	8.7	-	-	-
Alton	-	-	-	-	12.4	-	-	-

(Sheet 3 of 3)

Table 2
Average Percentages of Recreational Boating Traffic Use for Pools in the UMR-IWW System Used in the Recreational Traffic Forecasting Model

Pool	Average Percentage[1]
UMR-St. Paul District	
U/L SAF	1.61
Pool 1	0.20
Pool 2	3.00
Pool 3	33.78
Pool 4	15.25
Pool 5	3.22
Pool 5A	3.17
Pool 6	3.82
Pool 7	4.56
Pool 8	12.46
Pool 9	7.68
Pool 10	11.25
Sum	**100**
UMR-Rock Island District	
Pool 11	7.91
Pool 12	10.32
Pool 13	10.33
Pool 14	10.93
Pool 15	8.82
Pool 16	9.98
Pool 17	5.05
Pool 18	7.68
Pool 19	12.46
Pool 20	1.73

(Continued)

[1]For the St. Paul District: calculated from GREAT 1980a; Kelly 1993; Macbeth 1995; Carlson et al. 1995; USAED, St. Paul, 1995; Macbeth 1996.
For UMR pools in the Rock Island District: calculated from GREAT 1980a; Carlson et al. 1995.
For the St. Louis District: calculated from GREAT 1980a; Carlson et al. 1995.
For IWW pools in the Rock Island District: calculated from Carlson et al. 1995.

Table 2 (Concluded)	
Pool	**Average Percentage[1]**
UMR-Rock Island District (cont.)	
Pool 21	9.79
Pool 22	4.99
Sum	**100**
UMR-St. Louis District	
Pool 24	11.31
Pool 25	16.31
Pool 26	55.29
Pool 27 and Open River	17.08
Sum	**100**
IWW-Rock Island District	
Lockport	1.7
Brandon Roads	0.0
Dresden Island	5.2
Marseilles	6.4
Starved Rock	10.8
Peoria	54.8
LaGrange	8.7
Alton	12.4
Sum	**100**

Only two studies have information that can be used in estimates common to all of the UMR Pools: the GREAT studies (1980a, 1980b, 1981) and Carlson et al. (1995). The GREAT studies did not include estimates for the IWW. For pools in the St. Paul District (UMR Pools 1-10), a number of other studies that contain information related to the pool-level distribution of boating, which were mentioned previously, were also considered. The pool distribution figures are shown for each study in Table 1. With the exception of the data for Carlson et al. (1995), all pool distributions were taken directly from the original sources and adjusted to conform to the four regional groupings as necessary for comparability.

To create estimates of percentage of boating use by pool from the data from Carlson et al. (1995), an equal distribution of all use was made to the respective sampling units (each marina slip was credited with an equal share of marina use; each low-use boat ramp in a given region was credited with an equal share of that total use; etc.). This is a fairly crude method, since there is a great deal of

variation among high- and low-use sites. However, it is not an unreasonable approach given the lack of additional information and resources. A further limitation of this approach is that boating is distributed according to the pool of access and does not account for boaters who might spend time in other pools. In most pools, there is not a high percentage of traffic going between pools, based on USACE lockage data. However, in certain areas, such as Lock and Dam 3, there is a large amount of traffic between pools, which may not be adequately accounted for with these data. The distributions by pool are shown in Column 6 of Table 1.

The selection of the estimates or averages deemed the most reasonable for use in the forecasting model (Table 2) was based on different reasoning for each region. For Pools 1-10, the best pool-by-pool distribution data are clearly from the MWBAC Recreational Boating Study (MacBeth 1996), since it has been measured through time on a biennial basis. One shortcoming of the data is the incomplete coverage on Lake Pepin and backwater areas in other pools because of physical constraints that prohibit photographing boats across the full width of the river. The river is too wide in these areas for the procedure to be effective.

This shortcoming was accounted for by making assumptions about the missed traffic based on the professional judgment of resource managers most familiar with these pools. It was assumed that Lake Pepin accounted for 10 percent of all use in Pools 1-10 (effectively doubling the counts for Pool 4). In Pool 3, unobserved backwater use was assumed to add 10 percent to the use of that pool. In Pools 5, 5A, 6, and 10, 25 percent was added, and in Pools 7, 8, and 9, 50 percent was added. All figures for pool totals were then recalculated, returning to a balance of 100 percent for the St. Paul District Pools. After this adjustment, the average of the distributions measured for the 1989, 1991, and 1995 seasons were used in the forecasting model (Table 2).

For Pools 11-22 and Pools 24-27 (and open river), only two sources for estimates were found (Table 1). The two sources result in different estimates for each pool, although the differences are small. Since information is lacking that would definitively support one source over the other, a simple average of the two sources has been used for the forecasting model (Table 2). For the IWW Pools, the only source of use information found was from Carlson et al. (1995), so this distribution has been used for the forecasting model. To calculate a baseline total annual use on a pool-by-pool basis, the percentages listed in Table 2 were multiplied by the current (i.e., 1989-1990) recreational traffic data developed by Carlson et al. (1995) for each USACE District.

The potential exists for introducing bias and imprecision into estimates of within-pool recreational traffic based on interpolation and extrapolation of the data collected in the studies previously described. Once past the initial (and uncertain) estimates of total system use, the forecasting model has extended beyond currently available data and assumes the form of successively more detailed speculations. One issue concerns the representation of overall system- and district-level use by a small temporal sample size. For example, the 1989-90 data provide only a snapshot of recreational boating on the UMR-IWW System.

Despite the underlying uncertainty, the model projections do provide values that can be examined for common-sense validity. In addition, the traffic projections are also directly amenable to verification through field observations. Furthermore, it might be argued that, as with the commercial traffic ecological risk assessments, the focus is on incremental impacts of increased traffic.

Annual Use by Pool for the Year 2000

In the absence of comprehensive and detailed data that describe trends in recreational boating use on the UMR-IWW System, a lower range of future boating pressures might be projected as simply maintaining the current status quo (Figure 3). Assessing the effects of current use levels maintained through time in this way establishes a baseline that may prove useful for comparing with other projection scenarios.

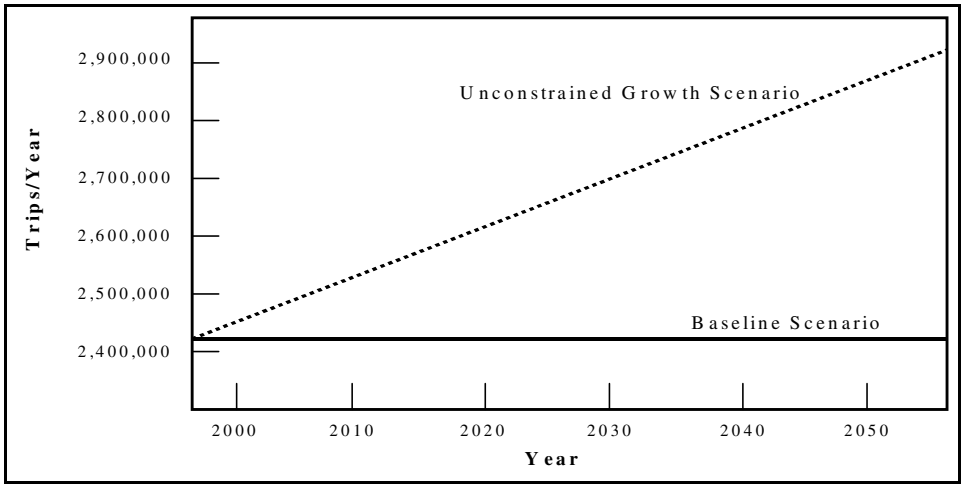

Figure 3. An example of the baseline and unconstrained growth scenarios for projected recreational traffic increases in the UMR-IWW System for 2000-2050

In the development of the recreational traffic forecasting model, the current annual use by pool data were adjusted using an expected 4.5 percent increase to generate the year 2000 baseline figures presented in Table 3 (Figure 2). These resulting traffic values (i.e., the year 2000 projections) could be assumed to remain constant for the project period of interest and thereby serve as a lower limit on likely future recreation traffic projections for the UMR-IWW System (Figure 3). One key assumption in developing this constant baseline projection is that recreational traffic will not decrease during the period of interest. The baseline projection rests on the assumption that fuel costs will not significantly increase, that public interest in boating will remain unchanged, and that points of access to and the physical infrastructure of the river system will be maintained to the level that supports current boating activity.

Forecasting to the years 2010, 2020, 2030, 2040, and 2050

Estimated increases in recreational boating traffic over the years 2000-2050 were developed using different data and assumptions, largely concerning the possible patterns of increase in human populations in the states bordering the UMR-IWW System. Several methods, which are briefly described in Chapter 5 of this report, have been routinely used by recreational professionals to project changes in recreational traffic: extension of past trends, simple regression, multiple regression, demand modeling approach, resource capacity, informed judgment, and market surveys (Walsh 1985; Ward et al. 1996). In addition to the selected method described in the following section, these methods were considered for projecting growth and forecasting recreational traffic.

The unconstrained use scenario, a linear, population-based projection

To complement a lower bound on future recreational traffic estimated by assuming that the year 2000 projected trips/day is a status quo, a simple approach to projecting future recreational boating use is to relate boating to anticipated future population changes. This can be done at the pool level by identifying which counties account for the majority of use for each pool. Population projections for these market area counties can then determine the expected corresponding change in recreational use in each pool during the project period.

To develop projections in this way, population projections for the five states bordering the UMR-IWW System were made to the year 2050. The projections are based on computations prepared by the respective states, to the extent they were available (Missouri State Demographer 1994; Goudy 1995; Illinois Department of Commerce and Community Affairs 1995; Iowa Department of Public Health 1995; Minnesota State Demographer's Office 1995; Wisconsin Department of Administration 1995) and by the U.S. Bureau of Economic Analysis (USBEA) (USBEA 1995).

The state-prepared population figures were provided for both the state and county levels. For Iowa, Minnesota, Missouri, and Wisconsin, projections were made to the year 2020. Projections were made to the year 2005 for Illinois. Projections prepared by USBEA were made to the year 2045, but these projections were for the state level only (USBEA 1995).

The population projections provided by the states were prepared under a variety of methods, relying on various sets of assumptions. Projections made by USBEA typically exceeded those prepared by the states and were adjusted downward to maintain consistency with the state-prepared approaches.

Population forecast to 2050

Three separate techniques based on different uses of the available demographic projections, which are summarized in the following paragraphs,

Table 3
Recreational Boating Use Projections by Pool and District (Unconstrained)

Pool	2000	2010	2020	2030	2040	2050	Growth	Percent Increase
UMR-St. Paul District								
SAF	23,011	24,720	26,247	27,573	28,977	30,463	7,452	32.4
1	2,859	3,071	3,260	3,425	3,600	3,784	926	32.4
2	42,878	46,035	48,852	51,313	53,914	56,664	13,786	32.2
3	482,806	516,871	547,687	574,769	603,360	633,559	150,754	31.2
4	217,963	226,226	233,635	240,910	248,539	256,542	38,579	17.7
5	46,022	47,027	47,849	48,857	49,899	50,979	4,957	10.8
5A	45,308	46,271	47,060	48,038	49,049	50,096	4,789	10.6
6	54,598	56,862	59,129	61,285	63,546	65,918	11,321	20.7
7	65,174	67,742	70,263	72,695	75,241	77,907	12,733	19.5
8	178,086	184,324	190,747	196,997	203,529	210,358	32,272	18.1
9	109,768	109,703	110,681	112,193	113,739	115,320	5,553	5.1
10	160,792	161,327	162,095	163,744	165,381	167,004	6,211	3.9
St. Paul District	1,429,264	1,490,180	1,547,506	1,601,800	1,658,775	1,718,596	289,311	20.2
UMR-Rock Island District								
11	54,307	55,439	56,529	57,754	58,989	60,230	5,923	10.9
12	70,853	72,227	73,509	75,249	76,900	78,591	7,738	10.9
13	70,922	72,822	74,978	77,568	80,237	83,035	12,113	17.1
14	75,041	77,831	80,944	84,859	88,335	92,005	16,964	22.6
15	60,555	62,208	64,104	66,941	69,274	71,719	11,164	18.4

(Sheet 1 of 3)

Table 3 (Continued)

Pool	2000	2010	2020	2030	2040	2050	Growth	Percent Increase
UMR-Rock Island District (conc.)								
16	68,519	70,516	72,775	75,932	78,626	81,425	12,907	18.8
17	34,671	35,875	37,218	38,903	40,409	41,985	7,314	21.1
18	52,728	54,919	57,407	59,748	62,420	65,254	12,526	23.8
19	85,614	87,960	90,703	94,023	97,414	100,986	15,371	18.0
20	11,878	11,854	11,887	12,259	12,480	12,709	832	7.0
21	67,214	66,770	66,707	68,824	69,936	71,094	3,880	5.8
22	34,259	34,290	34,474	35,675	36,401	37,176	2,916	8.5
Rock Island District-UMR	686,562	702,713	721,234	747,736	771,422	796,210	109,648	16.0
UMR-St. Louis District								
24	30,840	31,693	32,710	33,942	35,272	36,703	5,863	19.0
25	44,473	48,005	51,695	54,704	58,328	62,284	17,811	40.1
26	150,790	154,676	159,277	164,576	170,521	177,033	26,244	17.4
27& Open River	46,573	48,090	49,772	51,571	53,594	55,793	9,220	19.8
St. Louis District	272,676	282,463	293,453	304,793	317,716	331,813	59,137	21.7

(Sheet 2 of 3)

Table 3 (Concluded)

Pool	2000	2010	2020	2030	2040	2050	Growth	Percent
IWW-Rock Island District								
Lockport	5,532	5,887	6,272	6,633	7,049	7,495	1,963	35.5
Brandon Roads	0	0	0	0	0	0	0	0.0
Dresden Island	16,920	18,008	19,188	20,293	21,568	22,933	6,013	35.5
Marseilles	20,825	21,103	21,431	22,446	23,086	23,751	2,926	14.1
Starved Rock	35,142	35,611	36,164	37,878	38,958	40,080	4,937	14.0
Peoria	178,314	183,281	188,901	198,429	206,241	214,498	36,184	20.3
LaGrange	28,309	29,374	30,559	32,164	33,649	35,227	6,918	24.4
Alton	40,349	42,737	45,435	47,783	50,726	53,914	13,565	33.6
Rock Island District-IWW	325,391	336,002	347,949	365,626	381,278	397,897	72,506	22.3

(Sheet 3 of 3)

were developed to extend the states' county-level projections to the year 2050. These analyses resulted in part from suggestions made by state demographic planners. Criteria for selecting these methods included consistency among the states given the varied data available, reasonableness of the assumptions, and practicality of implementation.

Method I: Extrapolate recent trends in population change. The first method was based entirely on data and projections prepared by the individual states that border the river system. The rate of change for the last period available for each state and county was applied in each of the subsequent 10-year periods to the year 2050. This method for projecting growth sometimes resulted in county estimates that differed slightly from the state totals for the respective periods; the sum of the values by county were used to calculate the state total in these cases. This method results in counties growing or shrinking at the same rate through the period of interest. For pool segment i and year $k = 0, 1, 2, ...4$ ($k(0) = 2000$, $k(1) = 2010$, ... $k(5) = 2050$), the projected increase in total recreational boat trips/year $TPY(I)_{i,t(k+1)}$ was estimated by the first method as:

$$TPY(I)_{i,t(k+1)} = TPY_{i,t(k)} \cdot \sum_{m=1}^{S_i} \sum_{n=1}^{C_{Si}} \left[a_{m,n} \left(P_{m,n,t(f)} - P_{m,n,t(k)} \right) \Big/ P_{m,n,t(k)} \right] \quad (1)$$

where

S_i = the number of states bordering river segment i

C_{Si} = the counties within each state used in the calculation

$a_{m,n}$ = 0.75 for counties within 25 miles of the river (Zone 1)
0.25 for counties between 25 and 50 miles of the river (Zone 2),
otherwise 0

$P_{m,n,t(f)}$ = the final available population size for county n in state m

$P_{m,n,t(k)}$ = the population size for county n in state m and year k

Method II: Maintain proportions between counties through time. The second method for projecting growth relied on state-prepared data to determine the distribution of population among counties for each state. The distribution for the final period available for each state was held constant through each of the subsequent periods to the year 2050. This method results in all counties growing proportionately with the state, regardless of previous trends at the county level.

USBEA projections of state totals were used for years beyond those prepared by the states. The USBEA projections were adjusted proportionately for consistency with levels of the state-prepared projections for earlier periods. These adjustments were made to avoid a large discontinuity in the numbers that resulted simply from switching from state-prepared projections to USBEA estimates. Using the second method, the projected increases in total trips/year

($TPY(II)_{i,t(k+1)}$) were estimated according to the following equation for river segment i and year k = 0, 1, 2, ... 4:

$$TPY(II)_{i,t(k+1)} = TPY_{i,t(k)} \cdot \sum_{m=1}^{S_i} \left[\left(P_{m,t(f)} - P_{m,t(k)} \right) \Big/ P_{m,t(k)} \right] \quad (2)$$

where

$P_{m,t(f)}$ = the final available population size for state m

$P_{m,t(k)}$ = the population size for state m and year k

Method III: Extend changes in relative proportions between counties. Data prepared by the states were used to determine the rate of change in the relative distribution of population among counties for each state in this third method. The rate of change in the relative distribution for the final period available for each county was held constant through each of the subsequent periods to the year 2050. The resulting distributions were apportioned to the adjusted USBEA state-level projections, as described in the second method. Projected trips/year ($TPY(III)_{i,t(k+1)}$) for river segment i and year k = 0, 1, 2, ...4 were estimated by the third method according to the following equation:

$$TPY(III)_{i,t(k+1)} = TPY_{i,t(k)} \cdot \sum_{m=1}^{S_i} \sum_{n=1}^{C_{Si}} \left[a_{m,n} \left(R_{m,n,t(f)} - R_{m,n,t(k)} \right) \Big/ R_{m,n,t(k)} \right] \quad (3)$$

where

$R_{m,n,t(f)}$ = the final available relative population size for county n in state m

$R_{m,n,t(k)}$ = the relative population size for county n in state m and year k

The results of the three different demographic data analyses and projections are summarized in Figures 4-8. An average of the three projection techniques was used to make the final estimate of population growth during the project period. The unconstrained recreational traffic forecast, which is presented in Table 3 (the last step in Figure 2), was developed from the year 2000 projections using the same percentage increases in population growth derived from the demographic assessments. The total projected growth in boating trips from the year 2000 to 2050 is 19.6 percent for the UMR-IWW System as a whole, ranging from 16.0 percent for the Rock Island District to 22.3 percent for the IWW. These systemwide figures compare very closely with the U.S. Department of Agriculture Forest Service's nationwide regional demand projections for power-boating (English et al. 1993). In that study, powerboating was projected to increase by 20 percent from 1987 to 2040 in the North region (which includes the five states bordering the UMR-IWW System plus 15 other Great Lakes and East Coast states). However, the approach taken for the UMR-IWW System suggests that subregional growth is expected to vary substantially. Pool-level growth projections range from approximately 4 percent to over 40 percent across the system (Table 3).

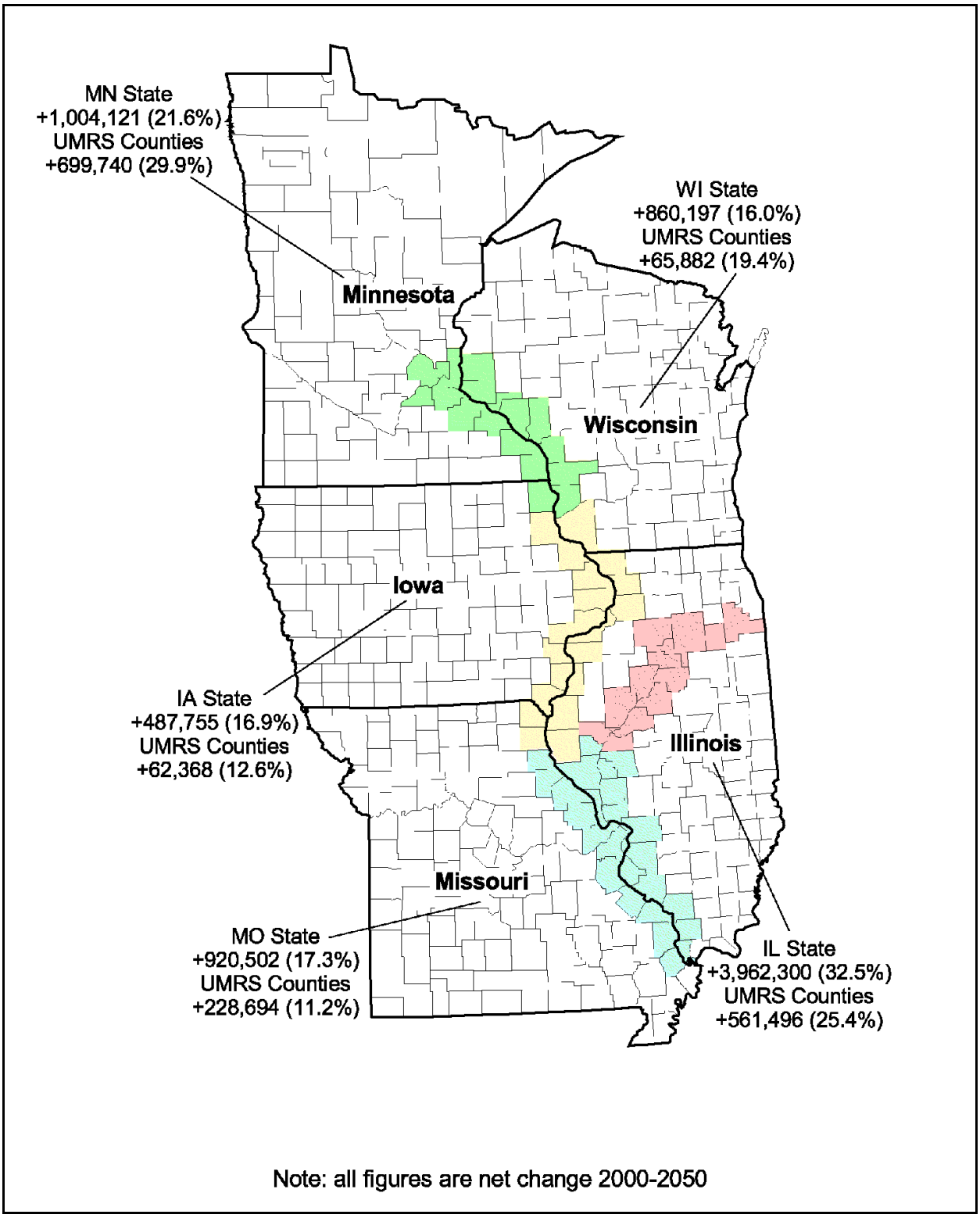

Figure 4. Population projections for the UMR-IWW System for the years 2000-2050, statewide and river county totals

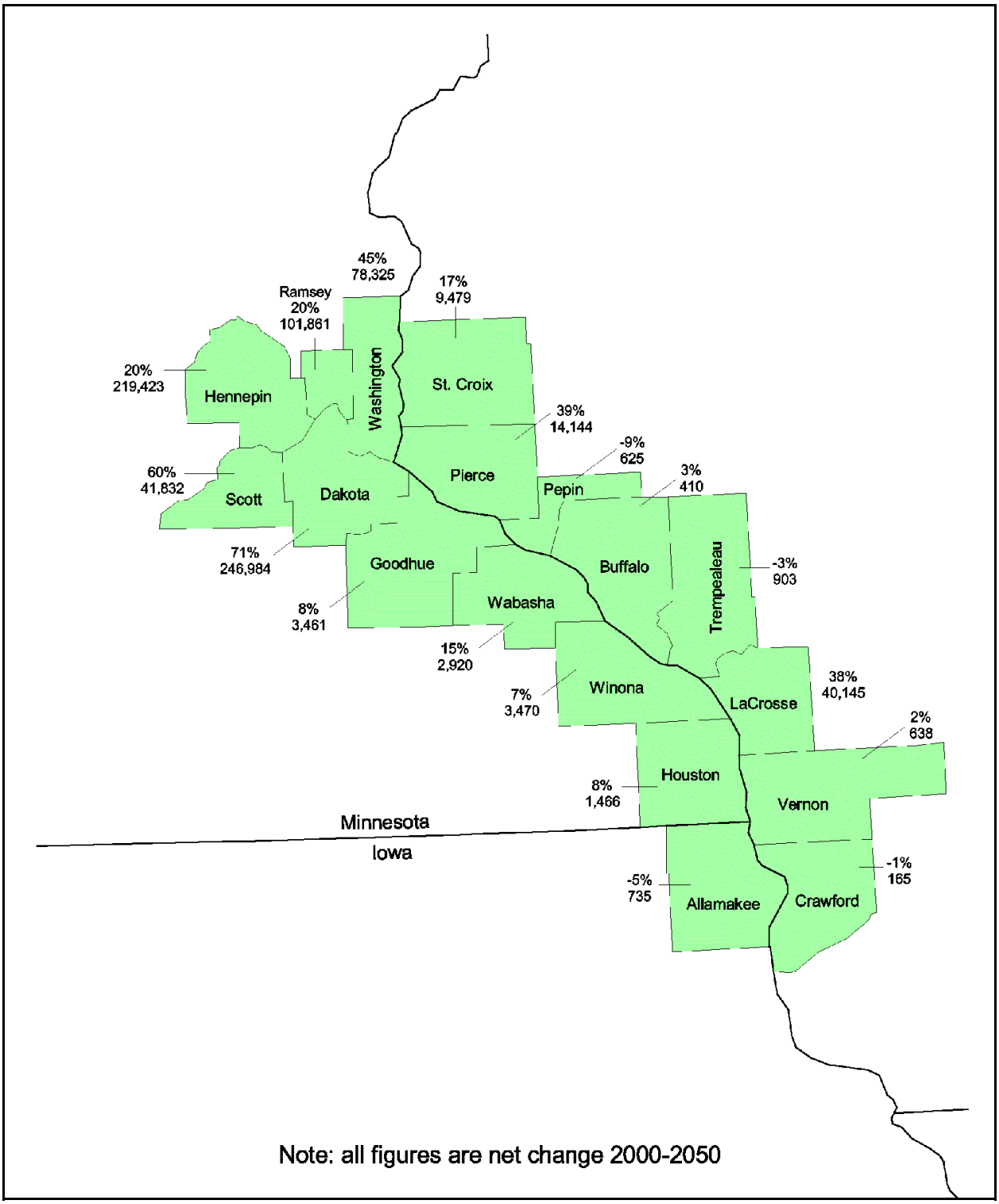

Figure 5. Population projections for the UMR counties for the years 2000-2050, St. Paul District

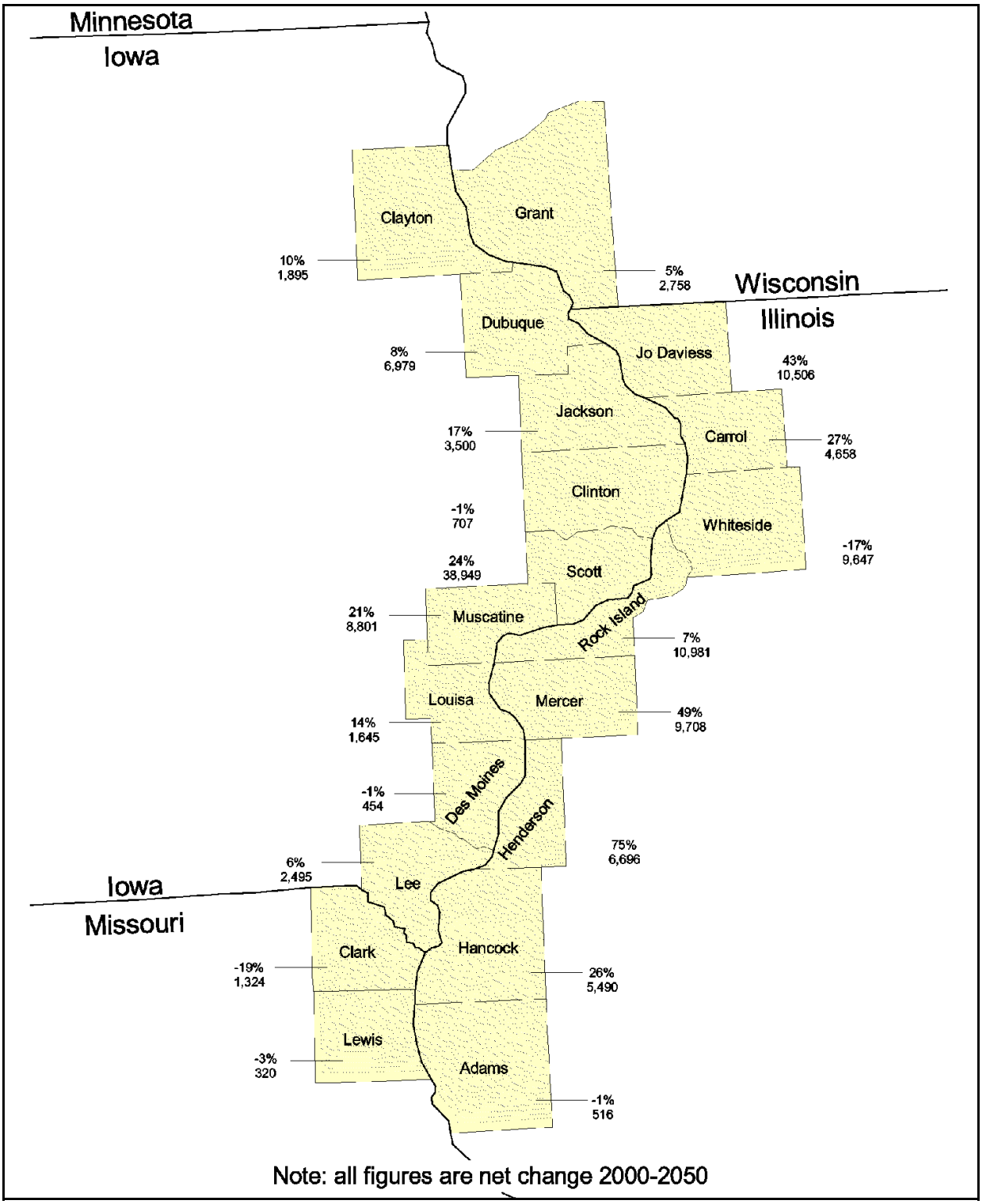

Figure 6. Population projections for the UMR counties for the years 2000-2050, Rock Island District

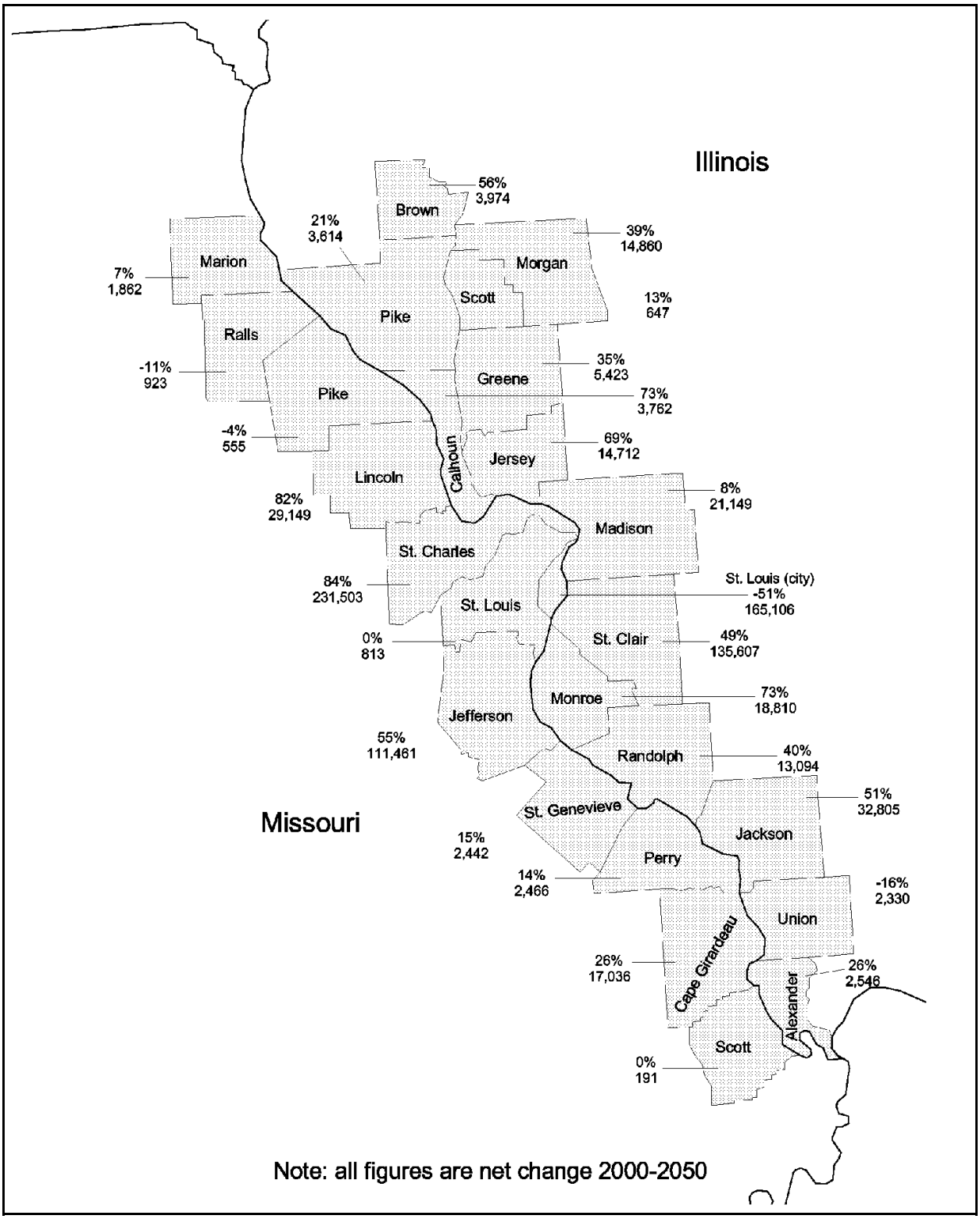

Figure 7. Population projections for the UMR counties for the years 2000-2050, St. Louis District

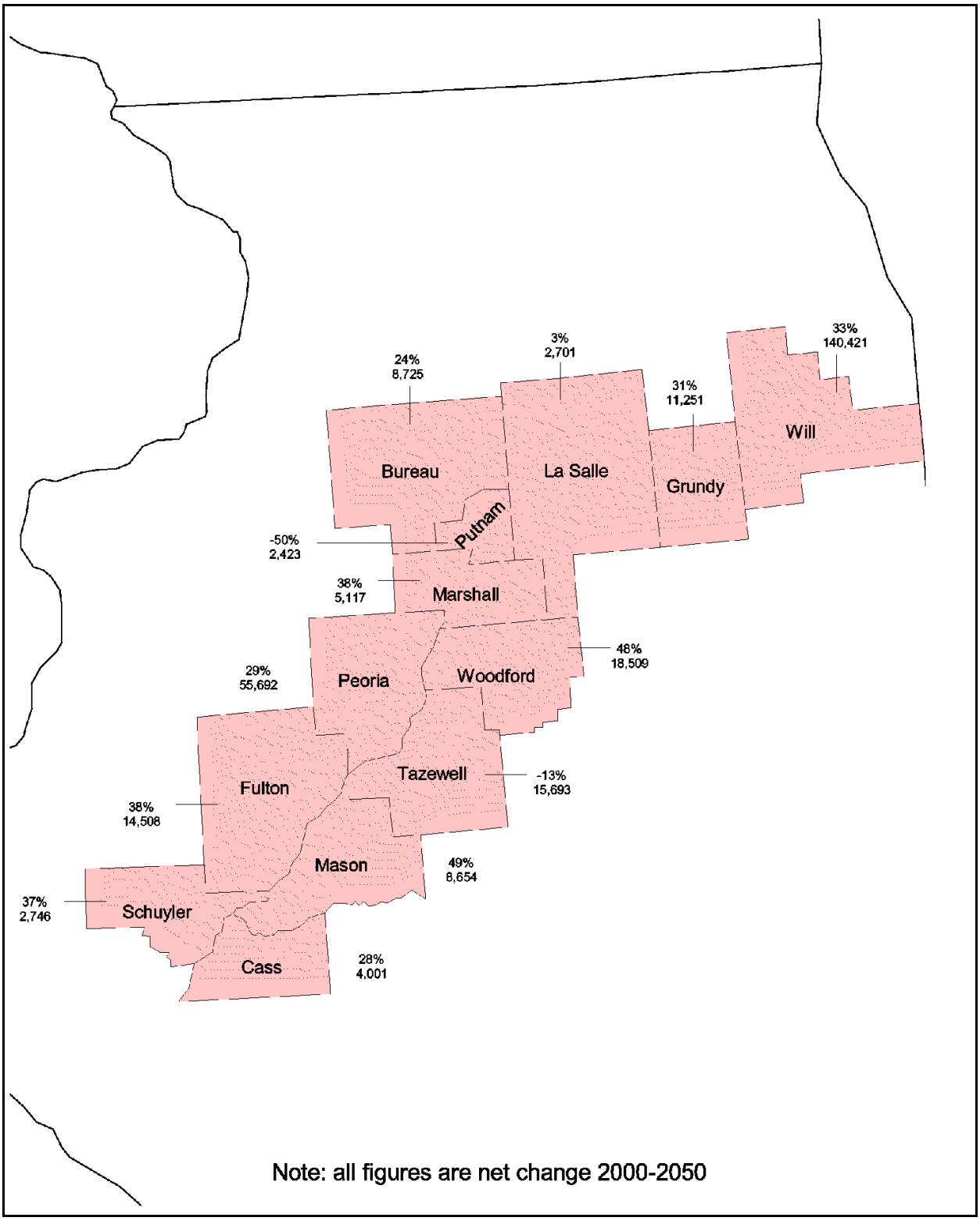

Figure 8. Population projections for the IWW counties for the years 2000-2050

This approach for developing recreational boating projections is based on population growth in primary and secondary market areas. These market areas have been defined by distance from each pool in the system. Carlson et al. (1995) described the primary market area as 40-48 km (25-30 miles), since in their study, three quarters of the recreational visitors to the UMR-IWW System lived within 48 km (30 miles) of the site they visited. An 80-km (50-mile) distance is typically observed as the limit for routine recreational trips and has been used to describe the secondary market area. These travel distances are consistent with those observed in numerous other UMR-IWW System studies, all of which confirm that the vast majority of visitation comes from local areas of 40 km (25 miles) or less (Fleener 1973, 1976; Penaloza 1992; Farabee 1993; Vogel, Titre, and Chilman 1996; MNDNR 1997).

This approach is a simplified version of the approach used in making recreation projections in the GREAT studies (GREAT 1980a, 1980b, 1981). An example map depicting the primary (Zone 1) and secondary (Zone 2) market areas for Pool 5A is shown in Figure 9; maps for each pool are contained in Appendix A. Counties were manually assigned to Zones 1 and 2 based roughly on 40- and 80-km (25- and 50-mile) distances from the respective pools, accounting for some anomalies based on precedents set in the GREAT studies or professional judgment.

Proportional growth in the primary and secondary market counties was used to project future use for each river pool (assuming a fixed per capita use rate or unconstrained projections). To complete this computation, the overall growth rates for Zone 1 and Zone 2 counties were computed separately for each pool. Three-fourths of the base-year use was projected to grow at the rate of the Zone 1 counties; the remaining one-fourth was projected to grow at the rate of the Zone 2 counties. This computation was made separately for each pool for each decade through 2050. The anticipated increase in trips to the year 2050 is shown in Table 3.

The major portion of the projected growth is expected to occur in a few concentrated areas. This is evident in the bar charts of the projected boating growth, shown by pool in each USACE District (in variable scales) in Figures 10-13. The largest increase, by far, is projected for Pool 3 in the St. Paul District of the UMR-IWW System (including the St. Croix River) with a total growth of 150,000 trips annually (Figure 10). Growth in the Rock Island District is fairly evenly distributed (Figure 11). In contrast, growth is more concentrated in the St. Louis metropolitan area (Pool 26) in the St. Louis District stretch of the UMR and in the Peoria Pool of the IWW (Figures 12 and 13). These areas are already commonly considered to be among the river's most crowded areas, at least during peak use periods.

One indicator of boating pressure that can be computed with the projections from this study is the number of annual boating trips per acre or density for each of the pools. This indicator falls short of representing crowdedness or carrying capacity, since spatial and temporal variation is not reflected in the calculation. Comparing the boating use figures to the number of acres in the most commonly

Figure 9

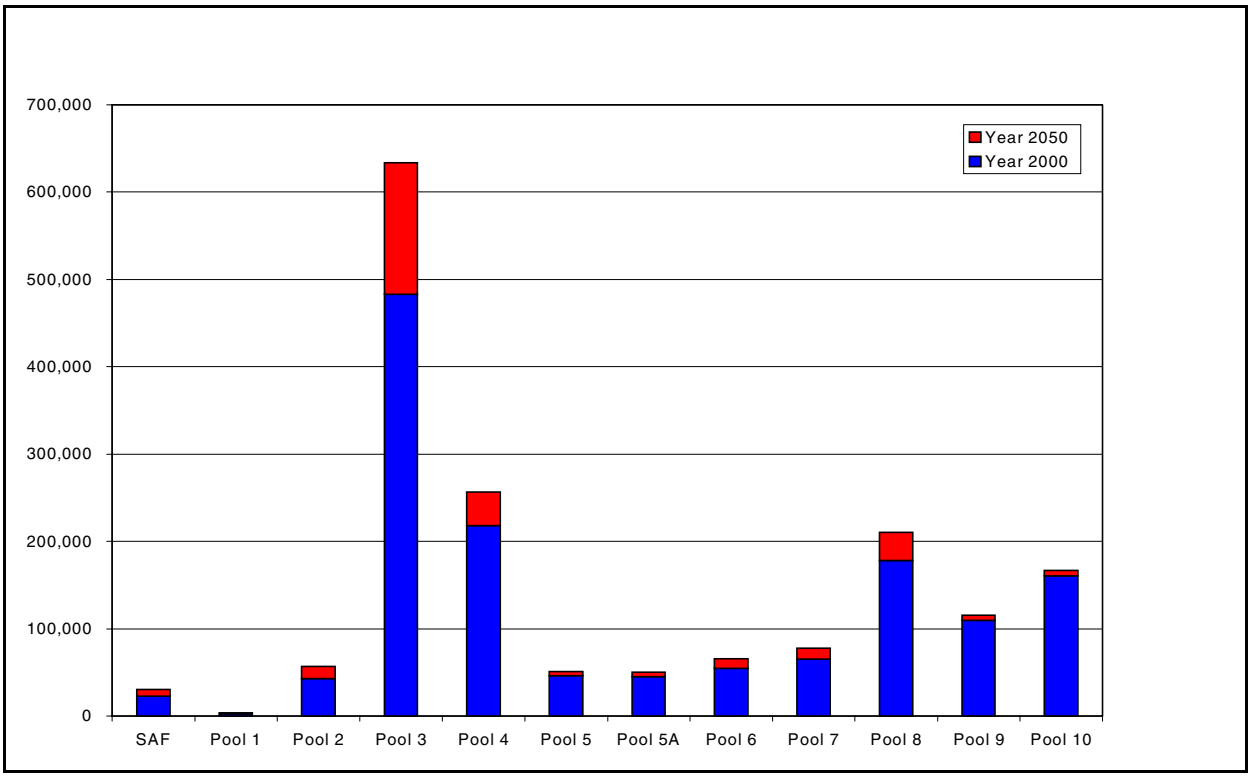

Figure 10. Recreational boating use projections by pool (unconstrained) for the St. Paul District

used areas would be a better measure, but the spatial data were not readily available at the time this report was being prepared. Despite these limitations, the calculations presented in Table 4 show the level of variation across pools throughout the system. The figures indicate that there are twice as many boat trips per acre in the St. Paul District as on the other stretches of the river system. The pools receiving the heaviest relative use are spread throughout the system, most notably in Pools 3, 8, 10, 15, and 21 of the UMR and in the Marseilles and Starved Rock Pools of the IWW.

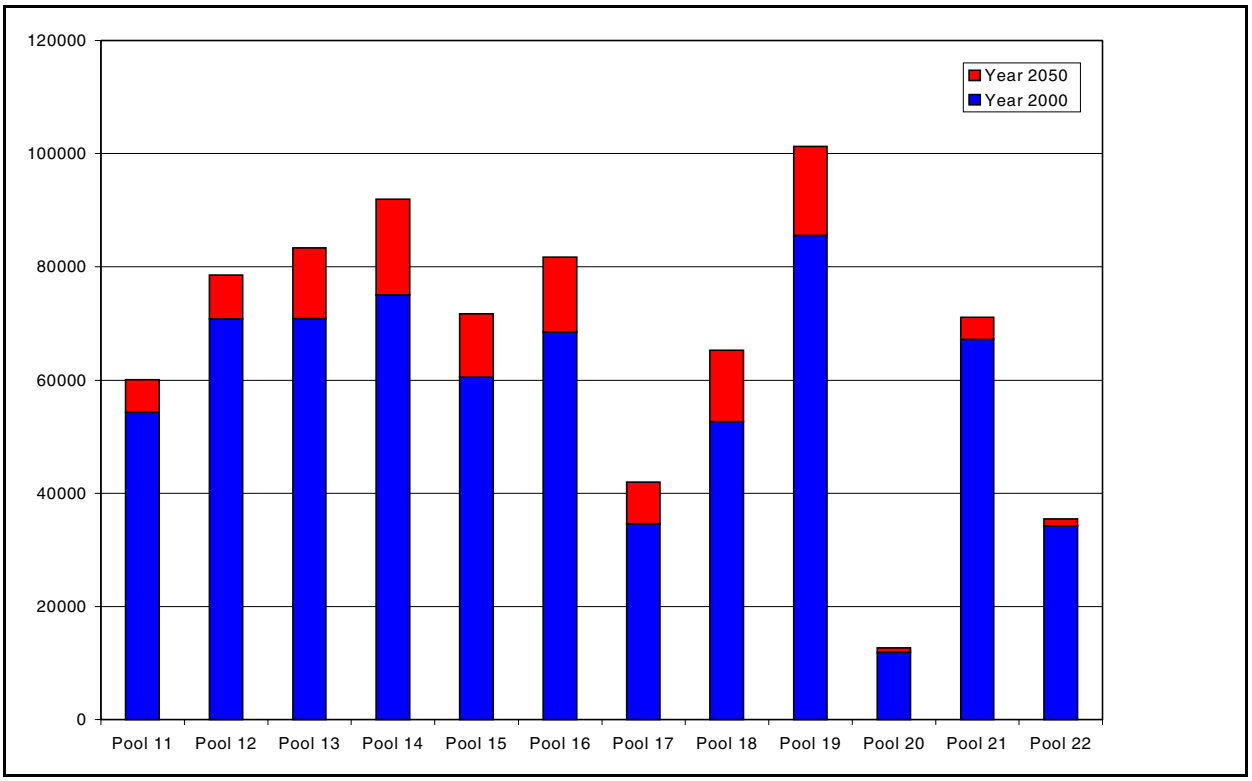

Figure 11. Recreational boating use projections by UMR pool (unconstrained) for the Rock Island District

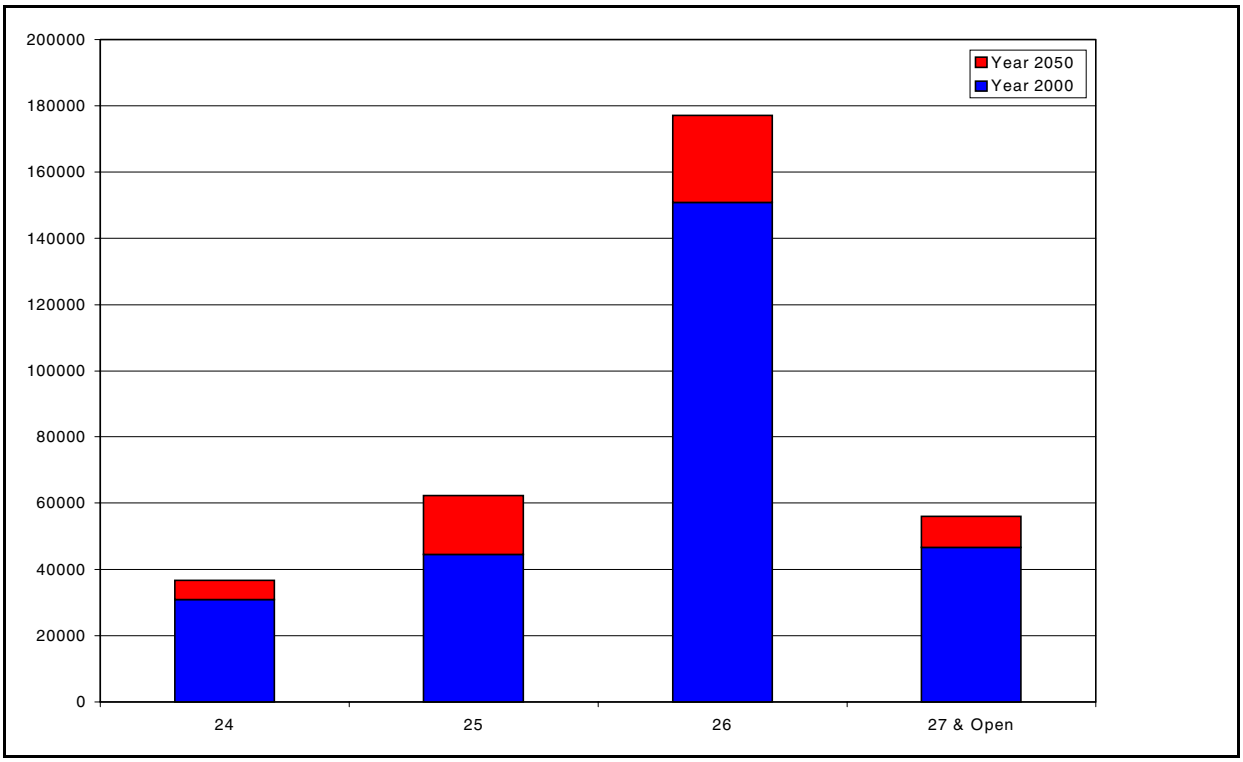

Figure 12. Recreational boating use projections by pool (unconstrained) for the St. Louis District

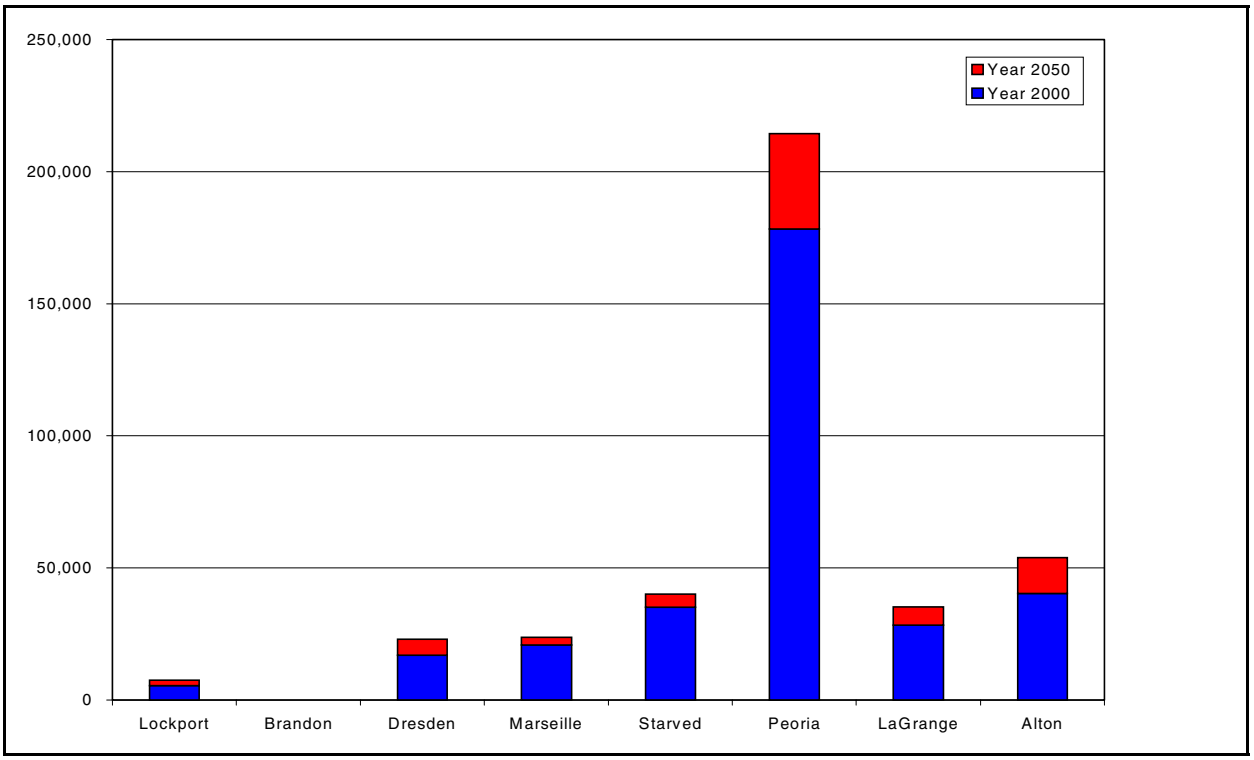

Figure 13. Recreational boating use projections by pool (unconstrained) for the IWW (Rock Island District)

Table 4
Changes in Recreational Boating Density from 2000 to 2050

Pool	Boat Trips in 2000	Pool Area, acres[1]	Density	Boat Trips in 2050	Density
St. Paul District-UMR					
SAF	23,011	n/a	n/a	30,463	n/a
1	2,859	546	5.2	3,784	6.9
2	42,878	9,652	4.4	56,664	5.9
3	482,806	26,165	18.5	633,559	24.2
4	217,963	35,198	6.2	256,542	7.3
5	46,022	10,838	4.2	50,979	4.7
5A	45,308	6,140	7.4	50,096	8.2
6	54,598	8,870	6.2	65,918	7.4
7	65,174	13,440	4.8	77,907	5.8
8	178,086	20,810	8.6	210,358	10.1
9	109,768	29,125	3.8	115,320	4.0
10	160,792	17,070	9.4	167,004	9.8
St. Paul District	1,429,264	177,854	7.9	1,718,596	9.5
Rock Island District-UMR					
11	54,307	15,000	3.6	60,230	4.0
12	70,853	19,000	3.7	78,591	4.1
13	70,922	29,103	2.4	83,035	2.9
14	75,041	10,450	7.2	92,005	8.8
15	60,555	3,740	16.2	71,719	19.2
16	68,519	13,000	5.3	81,425	6.3
17	34,671	8,312	4.2	41,985	5.1
18	52,728	13,600	3.9	65,254	4.8
19	85,614	30,854	2.8	100,986	3.3
20	11,878	7,542	1.6	12,709	1.7
21	67,214	6,350	10.6	71,094	11.2
22	34,259	8,540	4.0	37,176	4.4
Rock Island District-UMR	686,562	165,491	4.1	796,210	4.8
St. Louis District-UMR					
24	30,840	13,000	2.4	36,703	2.8
25	44,473	18,000	2.5	62,284	3.5
26	150,790	30,000	5.0	177,033	5.9
27 & Open River	46,573	n/a	n/a	55,793	n/a
St. Louis District	272,676	61,000	3.7	331,813	4.5

(Continued)

[1] To convert acres to square meters, multiply by 4,046.873.

Table 4 (Concluded)					
Pool	**Boat Trips in 2000**	**Pool Area, acres**	**Density**	**Boat Trips in 2050**	**Density**
		Rock Island District—IWW			
Lockport	5,532	n/a	n/a	7,495	n/a
Brandon Roads	0	455	0.0	0	0.0
Dresden Island	16,920	3,239	5.2	22,933	7.1
Marseilles	20,825	2,360	8.8	23,751	10.1
Starved Rock	35,142	3,188	11.0	40,080	12.6
Peoria	178,314	38,961	4.6	214,498	5.5
LaGrange	28,309	32,648	0.9	35,227	1.1
Alton	40,349	n/a	n/a	53,914	n/a
Rock Island District-IWW	325,391	80,851	3.5	397,897	4.2

3 The Recreational Traffic Allocation Model: Data, Methods, and Results

This chapter describes the recreational traffic allocation model and data sources and the methodology used to develop the model. In addition, results of the model simulations are presented.

Recreational Traffic Allocation Model

The allocation model uses the projected total recreational vessel trips per year per pool i and year k, $TPY_{i,k}$, to estimate the following for each pool, in sequence: the total trips per year for each vessel class j, $TVY_{i,j,k}$; the trips for each class in each month m, $TVM_{i,j,k,m}$; and finally, the number of trips per day for each vessel class for each day of the month, d, $TVD_{i,j,k,m,d}$ (Figure 14). Figure 15 schematically outlines the disaggregation process that constitutes the recreational traffic allocation model for a pool. The values of $TPY_{i,k}$ are the results of the recreational traffic forecasting model, previously described in Chapter 2. The model (written in FORTRAN) is included in Appendix B.

Trips per vessel class/year

In the current version of the allocation model, it was assumed that the relative distribution of the seven recreational vessel classes was the same for all pools of the UMR-IWW System. The vessel classes include sailboats, fishing boats, jet skis, pontoon boats, medium powerboats, large cruisers, and houseboats (Rust Environment & Infrastructure 1996a, 1996b). The model structure permits pool-specific distributions if supporting data become available. The percentages of the total trips per year k, for each pool i, and vessel class j, $PVA_{i,j}$, were estimated from available traffic data (Rust Environment & Infrastructure 1996a, 1996b). The number of annual trips for each vessel class was calculated as:

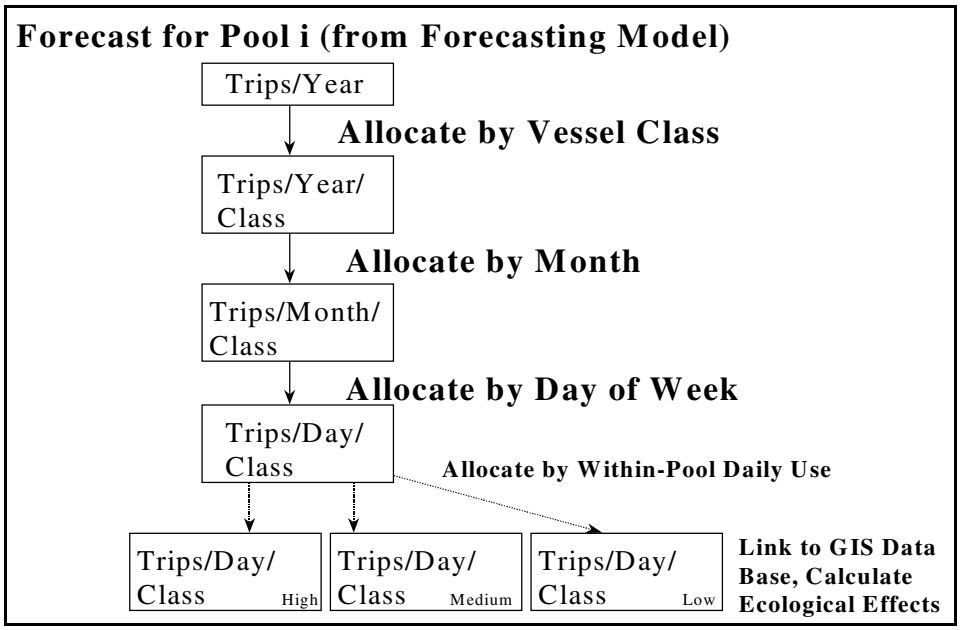

Figure 14. A schematic outline of the recreational traffic allocation model for a pool

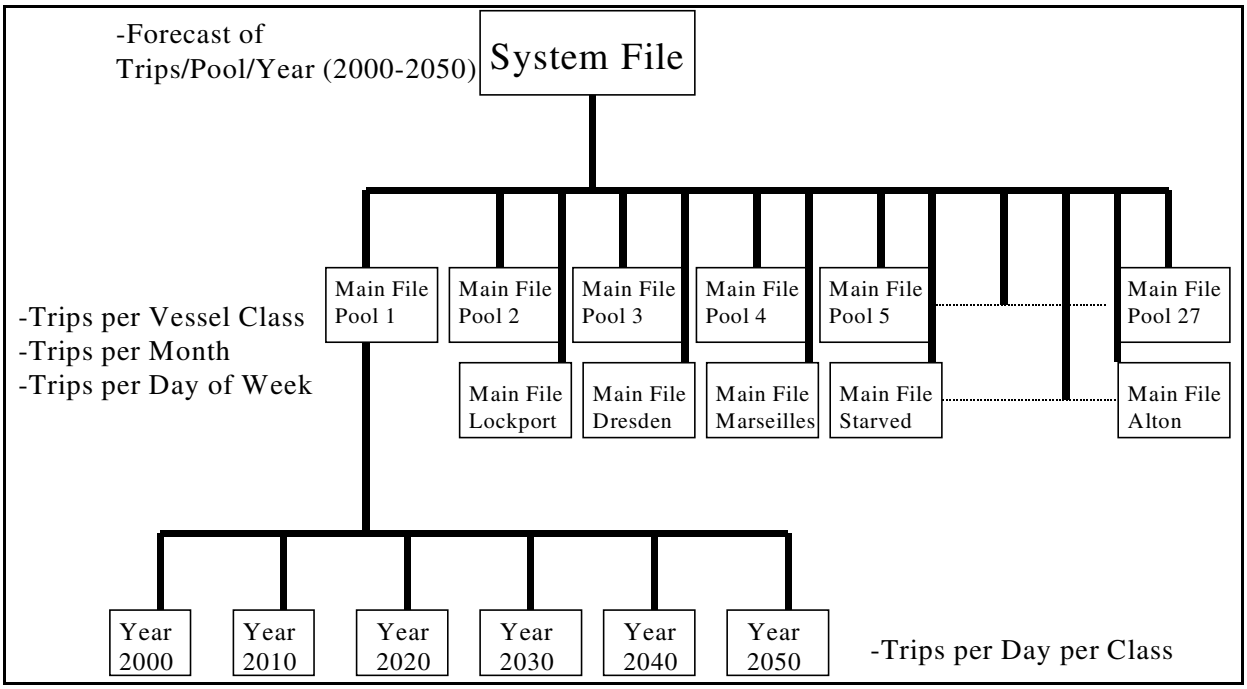

Figure 15. A schematic outline of the overall recreational traffic allocation model structure

$$TVY_{i,j,k} = TPY_{i,k} \cdot PVA_{i,j}\,, \qquad \text{for pool } i\text{, vessel class } j\text{, and year } k \qquad (4)$$

It was further assumed that the relative distribution of total trips among vessel classes would not change during the period of interest (e.g., 2000-2050). However, the model can be modified to accommodate changes in the relative distribution of future trips among different vessel classes if data that characterize such changes become available.

Trips per vessel class/month

For each year and pool, the calculated total number of trips/year for each vessel class, *TVY*, was subsequently partitioned to trips per month, *TVM*, based on data that described the relative distribution of annual trips among months for each vessel class (*PVM*) (Penaloza 1991; USAED, St. Paul 1993; Illinois Department of Natural Resources 1997). It was assumed that the proportional allocation among months was the same for each vessel class and each pool, although the model can use class- and pool-specific data if they become available. Trips per month were calculated for each vessel class according to:

$$TVM_{i,j,k,m} = TVY_{i,j,k} \cdot PVM_{i,j,k,m}\,, \text{ for pool } i\text{, vessel class } j\text{, year } k\text{, and month } m \qquad (5)$$

Trips per vessel class/day

For each year and pool, the calculated total number of trips/month for each vessel class, *TVM*, was subsequently partitioned to trips per day, *TVD*, based on data and assumptions that described the relative distribution of monthly trips among days of the week for each vessel class (Fleener 1976; Penaloza 1991; Vogel, Titre, and Chilman 1996; MNDNR 1997). In Equations 6 and 7, the w_m parameter partitions the monthly estimate, $TVM_{i,j,k,m}$, into equal total weekly trips. The value of w_m equals 7 divided by the number of days of the month. In terms of recreational traffic, it was assumed that each week in the month was identical. Within each week, half of the total weekly trips were allocated equally among the five weekdays (i.e., 10 percent/day); the remaining 50 percent was allocated equally between Saturday and Sunday traffic (i.e., 25 percent/day) (Fleener 1976; Penaloza 1991; Vogel, Titre, and Chilman 1996; MNDNR 1997). This daily allocation pattern was the same for each vessel class, pool, and month, although the model can use more specific data if they become available. Trips per day were calculated for each vessel class according to:

$$TVD_{i,j,k,d} = TVM_{i,j,k,m,d} \cdot 0.10 \cdot w_m\,, \text{ for pool } i\text{, vessel class } j\text{, year } k\text{, and weekday } d \qquad (6)$$

$$TVD_{i,j,k,m,d} = TVM_{i,j,k,m} \cdot 0.25 \cdot w_m\,, \text{ for pool } i\text{, vessel class } j\text{, year } k\text{, and Sat.-Sun.} \qquad (7)$$

It was additionally assumed that traffic allocations for Memorial Day, Independence Day, and Labor Day were equal to the weekend allocation for the corresponding week.

The allocation model has been developed as a sequence of calculations that progressively disaggregates (or partitions) available pool forecasts of total trips

per year (2000, 2010, 2020, 2030, 2040, and 2050) to more detailed estimates of trips per day by each vessel class within each pool (Figure 14). Ultimately, trips per day by each vessel class in specific use areas within each pool of the UMR-IWW System will be defined; for example, high-, medium-, and low-use areas within a pool will be defined for each vessel class. Thus, the model allocates coarse pool-level data to high-resolution estimates of within-pool daily use by different types of recreational vessels.

Data Sources Used to Develop the Recreational Traffic Allocation Model

The following sections describe the sources of data used to develop each of the allocations described in the previous section in the recreational traffic allocation model.

Use by vessel class

The numbers of total recreational boating trips/year forecast for each pool were used subsequently to develop trips/year numbers for different classes of recreational vessels (Figure 14).

Percentages of pool-specific total trips/year were calculated for each vessel class using the results of survey data obtained for four sampling areas on the UMR-IWW System and four areas on the IWW (Rust Environment & Infrastructure 1996a, 1996b). The numbers of different vessels observed during the survey are summarized in Table 5. The following percentages calculated using these data were assigned to vessel classes for all pools in the UMR-IWW System:

Vessel	Percentage
Sailboats	0.20
Fishing Boats	23.41
Pontoon Boats	2.78
Jet Skis	6.35
Medium Powerboats	40.48
Large Cruisers	24.01
Houseboats	2.78

These percentages were multiplied by the number of total trips/year forecast for each pool to estimate the number of trips per different vessel class per pool per year (Equation 4). One key assumption was that the percentages of different vessel types calculated from the survey data were representative of pools for which no direct measurements were available.

Table 5
The Number of Different Vessels Observed During the Summer 1996 Survey (Rust Environment & Infrastructure 1996b)

Vessel Data	Sampling Site and Dates Sampled			
	Red Wing, MN **July 19-20, 1996**	**LaCrosse, WI** **July 21 and 26, 1996**	**Quad Cities, IA/IL** **July 27-28, 1996**	**Grafton, IL** **August 4 and 9, 1996**
UMR				
Total Boats	504	504	504	480
Sailboats (1)	15	0	1	28
Fishing Boats (2A)	92	140	118	24
Pontoon Boats (2AP)	6	23	14	8
Jet Skis (2B)	16	40	32	91
Medium Powerboats (3)	193	190	204	208
Large Cruisers (4A)	155	75	121	79
Houseboats (4B)	27	36	14	42
Top Speed (mph)	57	61	64	50
	Peoria, IL **July 19-20, 1996**	**Pekin, IL** **July 20, 1996**	**Havana, IL** **July 27-28, 1996**	**Meredosia, IL** **August 2-3, 1996**
IWW				
Total Boats	125	69	125	155
Sailboats (1)	3	0	0	1
Fishing Boats (2A)	25	18	48	22
Pontoon Boats (2AP)	4	0	6	7
Jet Skis (2B)	12	13	10	17
Medium Powerboats (3)	70	37	44	64
Large Cruisers (4A)	11	1	17	43
Houseboats (4B)	0	0	0	1
Top Speed (mph)	48	45	59	53

Furthermore, in developing projections for the years 2000-2050, it was also assumed that the relative proportions of vessels in different classes would remain the same.

The limited number of sampling stations on the UMR-IWW System and timing of sample collection are likely to affect the accuracy and precision of

allocating annual traffic use within pools by vessel type. Quantifying these kinds of uncertainties remains subjective and relies on informed opinion.

Pool monthly and daily use by vessel class

Estimates of daily pool use were made by first apportioning the total trips/year for each vessel class among the months of the year (Equation 5), following seasonal patterns reflected in the data. This allocation was made based on the survey data from the Economic Impacts of Recreation Study (USAED, St. Paul, 1993). Although the seasonal information supporting the allocation is based only on trips originating from permitted boat docks and marina slips, the results closely correspond to those from statewide boating surveys conducted in Illinois (Illinois Department of Natural Resources 1997) and Wisconsin (Penaloza 1991). The monthly values used in the allocation model were based on the seasonal values of approximately 10 percent for spring (April 1-May 28), approximately 75 percent for summer (May 29-September 3), and approximately 15 percent for fall (September 4-November 14) (USAED, St. Paul, 1993). The following monthly values are used in the allocation model:

Month	Percentage
January	0
February	0
March	0
April	3.53
May	13.51
June	18.05
July	24.39
August	19.12
September	13.25
October	8.15
November	0
December	0

Recreational traffic was not measured in the UMR-IWW System from November through March. Fishing boats can occur year-round in the southern pools of the UMR (from Pool 19 south) and in some pools of the IWW. Northern pools on the UMR (i.e., Pools 1-13) and much of the IWW are ice-covered for several winter months. In addition, ice-out certainly proceeds from south to north each year, thereby providing longer boating seasons in southern pools. However, data describing such expected different monthly allocations have not yet been identified to support the inclusion of a north-south gradient in the allocation model.

The expert judgment provided in regional workshops (Rust Environment & Infrastructure 1996b) used to allocate seasonal patterns of use might be biased toward weekend sampling during months of fairly intensive use (i.e., the boating season). Additional inaccuracy and imprecision might exist in the allocation model owing to the simplistic assumptions concerning the allocation of different vessel class traffic within weeks of the month. The current model assigns certain percentages of total monthly traffic to each day of the month. However, all weekdays and all weekends are identical within each month in the current version of the model.

To obtain trips/day, the calculated monthly traffic values were further subdivided by estimated fractions of weekly use assigned to weekdays and weekends (Equations 6 and 7). Several recreational boating studies in the UMR that have separately recorded weekday and weekend/holiday use were used to support this allocation. There is strong agreement among the studies: total boating use is split nearly 50/50 between weekdays and weekends/holidays (Fleener 1976; Penaloza 1991; Vogel, Titre, and Chilman 1996; MNDNR 1997). Figures vary from 45 percent to 55 percent, balanced toward either weekends or weekdays, depending on the study. Therefore, the allocation of trips across days used in the model is 10 percent for each weekday (Monday through Friday) and 25 percent for each weekend day (Saturday and Sunday). Holidays (Memorial Day, Independence Day, and Labor Day) are treated as a weekend day.

Appendix C contains the results of daily projections by vessel class for Pool 13 on the UMR and the LaGrange Pool on the IWW as examples. Results for all pools in the UMR-IWW System are presented in Appendix B. These estimates will be used with the corresponding physical forces models to estimate risks posed by recreational vessels on ecological resources of concern in the UMR-IWW System.

4 Recreational Traffic Allocation Model Sensitivity and Uncertainty Analysis

Bias and imprecision (i.e., uncertainty) were inherent in the development of the recreational traffic forecasting and allocation models. Sparse data and incomplete understanding of the utilization of the UMR-IWW System by recreational boaters as well as assumptions associated with projecting the future growth of recreational boating contribute uncertainty to the model results.

This section describes sensitivity analysis and uncertainty analysis as numerical approaches for evaluating the impacts of bias and imprecision of the model input data (i.e., parameter values) on resulting model projections of recreational trips per day. Example applications of these methods to the analysis of the allocation model are provided to (a) characterize the impacts of parameter uncertainty on model results and (b) identify the key model parameters that contribute the greatest amount of uncertainty to the model results. The following sections briefly describe sensitivity analysis, uncertainty analysis, and the Monte Carlo simulation methods used to perform each analysis.

Sensitivity Analysis

Sensitivity analysis examines how the numerical structure of the model contributes to the translation of parameter uncertainty to variability of the model results. Model structure refers to the equation(s) that constitute the overall calculation. The allocation model is a simple series of multiplications. In contrast, many ecological models consist of linear or nonlinear regression equations or sets of complex differential equations that might include highly nonlinear terms. In calculus, sensitivity analysis equates to estimating the partial derivative of the model result to the parameter estimates. More simply stated, the analysis examines how the model structure responds to small variations in the parameter values used to perform the calculation. For some models, the partial derivatives can be described using analytical calculus. For more complex models

that defy analytical solution, the partials can be estimated using numerical techniques. Repeated model calculations using parameter values that are varied by a small degree (e.g., ±1 percent) provide reliable numerical approximations to the partial derivatives that strictly define sensitivity. The greater the value of the partial derivative of a parameter (or its numerical approximation), the more sensitive the model is to variability in the estimated value of that parameter.

Sensitivity analysis can be used in model development. For example, learning that a proposed model structure is sensitive to an exponent in a complicated, nonlinear model equation might lead to reformulation of the model. Results of such sensitivity analyses can also be used to rank-order the allocation of often limited resources to accurate estimation of the most sensitive model parameters. Numerical sensitivity analyses can be performed using Monte Carlo simulation methods, as described later in this section.

Uncertainty Analysis

Uncertainty analysis differs from sensitivity analysis in purpose and in the degree of variability assigned to model parameter values. Having an accepted model structure, uncertainty analysis characterizes the expected variability of model results given best estimates of uncertainty associated with model parameter values. While sensitivity analysis examines model structure, uncertainty analysis focuses on model performance. Instead of parameter values varying by ±1 percent, model parameters are assigned to distributions of values intended to realistically reflect their variability in application to the system of interest (e.g., the UMR-IWW System). Each model input parameter might have its own distribution; not all parameters will be equally uncertain; and not all parameters will be similarly distributed.

Uncertainty analysis can be used to evaluate model performance by (a) quantifying the distribution(s) of model results, given the best initial estimates of possible model parameter values and (b) identifying the key model parameters that must be more precisely estimated to increase the precision of model results. Uncertainty analyses are important, for example, if the model results are used in making decisions, and the initial model provides results too uncertain for the decision-making process. Uncertainty analysis will identify the important model parameters and the degree of precision required in their estimation in order to arrive at an unambiguous decision.

Monte Carlo simulation methods can also be used to perform uncertainty analyses as demonstrated by the example uncertainty analysis of the recreation traffic allocation model. Importantly, because the intent of the analyses and nature of specified parameter uncertainty differ between sensitivity and uncertainty analysis, the resulting identification and rank-ordering of parameter importance can also differ in these analyses of the same model.

Monte Carlo Methods

Monte Carlo simulation simply involves the repeated calculation of modeled results using different values of model input parameters in each calculation. Monte Carlo simulation is a convenient tool for incorporating uncertainties into mathematical calculations (Rubenstein 1981; U.S. Environmental Protection Agency (USEPA) 1997). Monte Carlo methods were used to assess the sensitivity and uncertainty of the traffic allocation model results to variations of the numbers used to perform the calculations. Monte Carlo methods require the model or calculation of interest and a random number table or a random number generator. A random number is a mathematically selected value that is generated by a formula or selected from a table to conform to a selected probability distribution. A computerized uniform random number generator produces a series of independent pseudo-random numbers that range from zero to one; all values within this range have an equal chance of being selected. Random numbers are used in Monte Carlo simulation to select values at random from the distributions that define the model input parameters.

To analyze sensitivity and propagate uncertainty through the model calculations using a Monte Carlo approach, the values of the input parameters are assigned to statistical distributions. A distribution for a model input can be selected by fitting data to different distributions and choosing the "best fit." Alternatively, distributions might be selected on the basis of theory or understanding that suggests a particular distribution. In many cases, some combination of empiricism, knowledge, and professional judgment is used to select a distribution.

In these analyses, model parameters were assigned to normal, uniform, or triangular probability distributions. The normal distribution describes variability for many natural phenomena. The arithmetic mean and standard deviation define a normal distribution of values that describe the familiar bell-shaped curve. The following three aspects of uncertainty in a model parameter might suggest using a normal distribution: (a) one value of the uncertain parameter is the most frequent (i.e., the mean of the distribution), (b) other values of the uncertain parameter are equally more or less frequent than the mean, and (c) the uncertain parameter values are more frequently similar to the mean than extremely greater or less than the mean. In the uniform distribution, all values between the minimum and maximum occur with equal likelihood. Two conditions of uncertainty suggest using a uniform distribution: (a) the minimum and maximum values of the parameter are quantified, and (b) all values between the minimum and maximum could occur with equal frequency. The triangular distribution describes a situation where the minimum, maximum, and most likely values to occur are known. The triangular distribution does not include extreme values found in the tails of the bell-shaped curve of the normal distribution. The following three conditions underlie use of the triangular distributions: (a) the minimum value is known, (b) the maximum value is known, and (c) the most likely value is between the minimum and maximum. The triangular distribution can approximate a normal distribution.

Once all the input parameters have been defined as distributions, the calculations (or simulations) are repeated using values selected at random from these distributions. The result is a distribution(s) of model results that reflects the implications of the combined uncertainties of the input values. The distribution(s) of results can be illustrated in the form of a frequency distribution, illustrated as a cumulative frequency distribution, or described statistically (i.e., percentiles).

Allocation Model Sensitivity Analysis

Sensitivity analysis characterizes the partial derivative of the selected model result to small variation in the values of model parameters (Bartell et al. 1986; Bartell, Gardner, and O'Neill 1992). The sensitivity of the traffic allocation model was evaluated to identify the key data, parameters, and assumptions that contribute to variability in the final projections of within-pool trips per day for each class of recreational vessels.

Using a Monte Carlo approach, variations in the model parameters were represented as statistical distributions. Repeated simulations of the allocation model with parameter values selected from their corresponding distributions using a stratified-random sampling procedure generated distributions of the allocation model results. Statistical methods were used to analyze the results of the Monte Carlo simulations and identify the most sensitive input parameters of the recreational traffic allocation model.

The allocation model, in theory, can estimate 127,750 different traffic values for each pool of interest in the UMR-IWW System (50 years × 365 days/year × 7 vessel classes). This amounts to a systemwide projection of more than 4 million values. Clearly, characterizing the sensitivity of all traffic projections is prohibitive both in terms of computational time and ability to interpret the monumental volume of model results. Therefore, one weekday (June 1, 2000) and one weekend day (June 3, 2000) for Pool 13 of the UMR were selected to be representative of typical summer traffic and analyzed as examples. It was assumed that these days were representative of all weekdays and weekend days (i.e., similar sensitivity to errors).

Parameter distributions

Four input values are required to get from an estimate of the total number of boat trips per year to the number of trips per day for each of the seven vessel classes. The first number is the estimated total number of trips per year in the pool of interest. For Pool 13, this value was forecast as 70,922 for the year 2000 (Table 3). The second parameter allocates a percentage of this number to the vessel category of interest (i.e., medium powerboats) (Equation 4). The third parameter allocates the percentage of the annual traffic to each month of the recreational boating season (Equation 5). The final parameter allocates a percentage of the monthly traffic to each day of the week (Equations 6 and 7).

To perform the numerical sensitivity analysis, the four input parameters were simultaneously varied ±1 percent from their initial values. The estimate of total vessels/year was defined as a uniform distribution; the remaining parameters were defined as normal distributions (Figures 16 and 17). One thousand Monte Carlo simulations were performed by selecting values from these distributions and calculating the number of medium powerboats expected for June 1, 2000 (Thursday), and June 3, 2000 (Saturday), Pool 13.

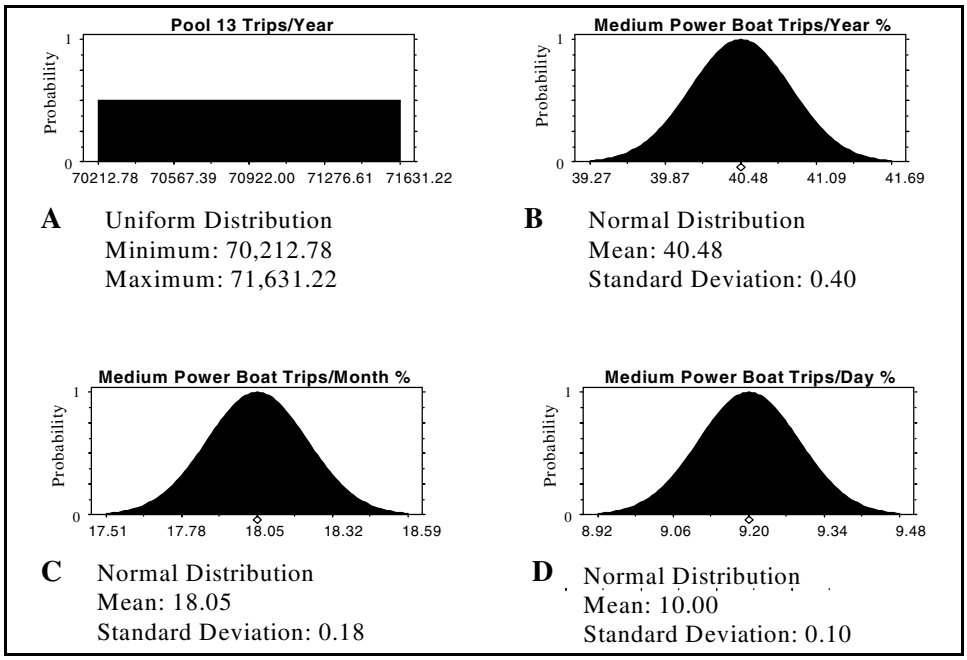

Figure 16. Descriptions of the distributions assigned to the model parameters for the sensitivity analysis for medium powerboats on June 1, 2000 (a weekday) on Pool 13 [(A) trips/year 2000/Pool 13, (B) trips/year 2000/medium powerboats/Pool 13, (C) trips/year 2000/June/ medium powerboats/Pool 13, (D) trips/year 2000/June/weekday/ medium powerboats/Pool 13]

Results

The results of 1,000 Monte Carlo simulations of the recreational traffic allocation model for medium power cruisers on the selected days are summarized in Figure 18. The slight variation in model input values results in estimates of trips/day on June 1, 2000 (weekday), ranging from 451 to 503 medium powerboats per day in Pool 13. The June 3, 2000 (weekend day), values range between 1,240-1,389 boats/day.

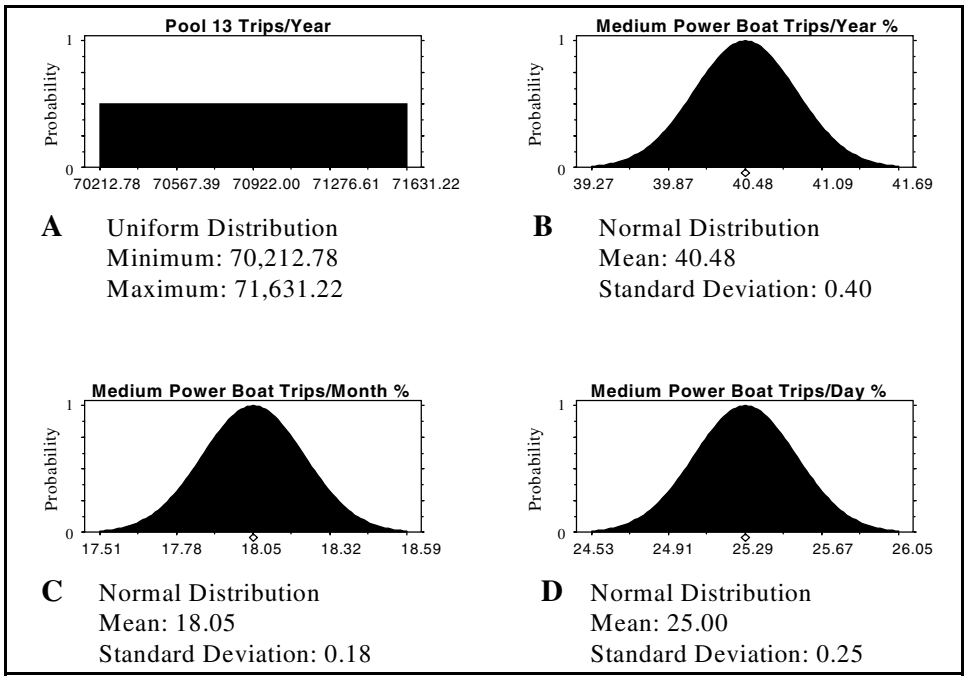

Figure 17. Descriptions of the distributions assigned to the model parameters for the sensitivity analysis for medium powerboats on June 3, 2000 (a weekend day) on Pool 13 [(A) trips/year 2000/Pool 13, (B) trips/year 2000/medium powerboats/Pool 13, (C) trips/year 2000/June/medium powerboats/Pool 13, (D) trips/year 2000/June/weekend day/ medium powerboats/Pool 13]

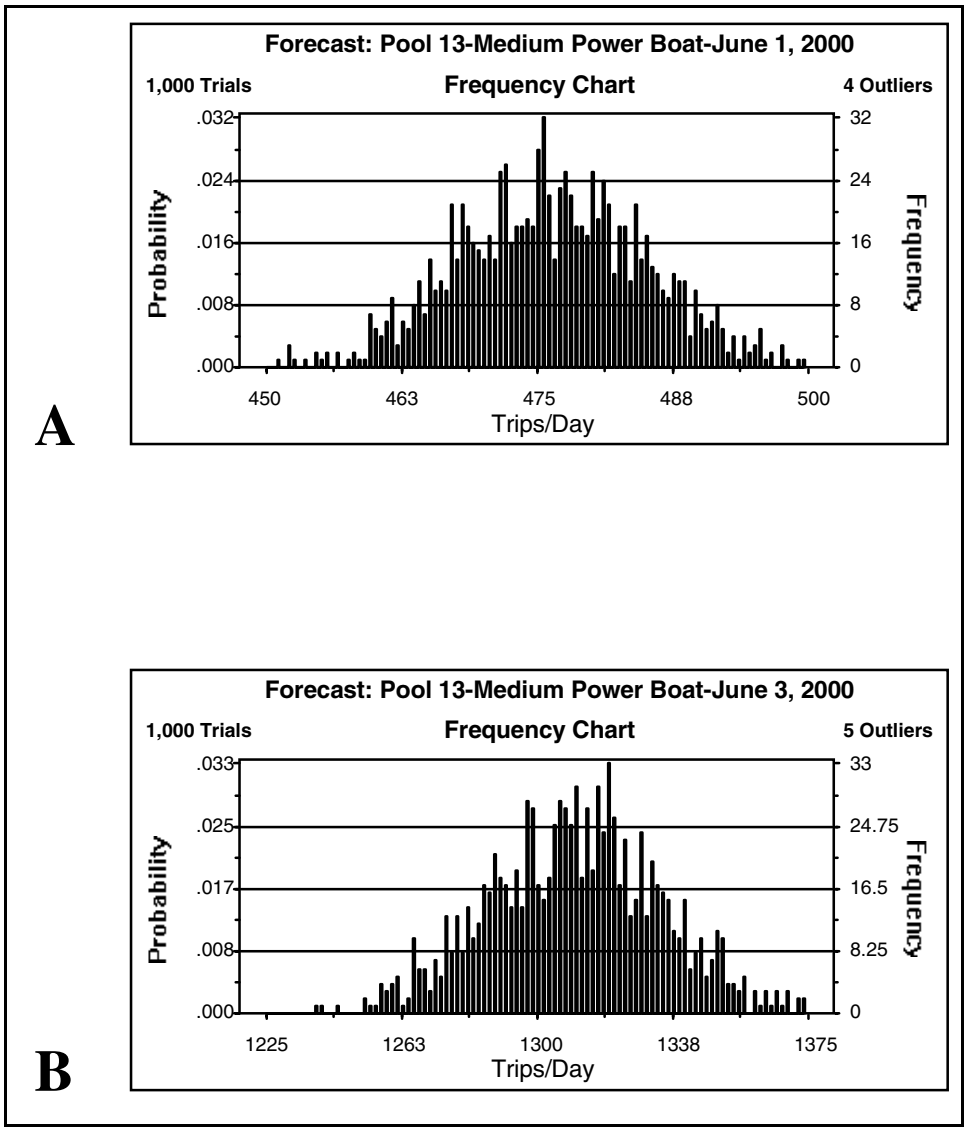

Figure 18. Frequency distributions resulting from the sensitivity analysis describing projected trips/day for medium powerboats on Pool 13 on June 1, 2000, a weekday (A) and June 3, 2000, a weekend day (B). Results are from 1,000 Monte Carlo simulations using the recreational traffic allocation model with 1 percent variation on four input parameters

The percentage of the variation in the model result explained by variation in each parameter was used to quantify model sensitivity and rank-order the four input values. If all four input parameters were of equal importance, each would account for approximately 25 percent of the variation in the estimated trips/pool/day. The sensitivity of the June 1 and 3, 2000, estimates to input parameters included in the analysis are illustrated in Figure 19. The results demonstrate the similarity of the importance of the allocation parameters with the annual total number of trips being the least sensitive parameter. The most sensitive parameter in each case was the percentage allocation of the annual total to the month of June. This was followed in importance by the percent allocation to the day of the week, the allocation of total trips to medium powerboats, and finally to the estimate of total recreational vessels/year in Pool 13 for June 1, 2000. The sensitivities for the June 3, 2000, estimates are similar except that the allocation to powerboats parameter and the allocation to day of the week are reversed in their order of importance. The relative insensitivity of the calculations to the initial number of trips per year resulted in part from assigning a uniform distribution with the minimum and maximum defined as ±1 percent of the mean value, whereas the ±1 percent value was used to define the standard deviation of the allocation parameters. Thus, the relative variance of the trips/year parameter was lower than the variance of the allocation parameters. The results of the sensitivity analysis reflect the underlying model structure, which is essentially a sequence of multiplications.

Implications

The results of the sensitivity analysis underscore the importance of all of the fundamental data used to develop the recreational traffic allocation model. Apart from the forecast of total annual trips per pool, the remainder of the allocation model consists of a series of percentage allocations, where parameter values can range only between zero and 100 percent. The similarity in model sensitivity to the percentage allocation parameters demonstrates the absence of nonlinear responses of model estimates to parameter sensitivity. The results also suggest that the model has been correctly coded into the software. That is, there were no unexpected extremely sensitive parameters.

Allocation Model Uncertainty Analysis

Model uncertainty analysis attempts to characterize the variability in model results using best estimates of the distributions of model parameter values. In contrast to sensitivity analysis, which uses equally small (e.g., 1 percent) perturbations to all model parameters, uncertainty analysis includes the potential for larger and different variances associated with each of the model inputs (Bartell, Gardner, and O'Neill 1992).

Parameter distributions

The main assumptions used in the uncertainty analysis of the recreational traffic allocation model take the form of the statistical distributions used to

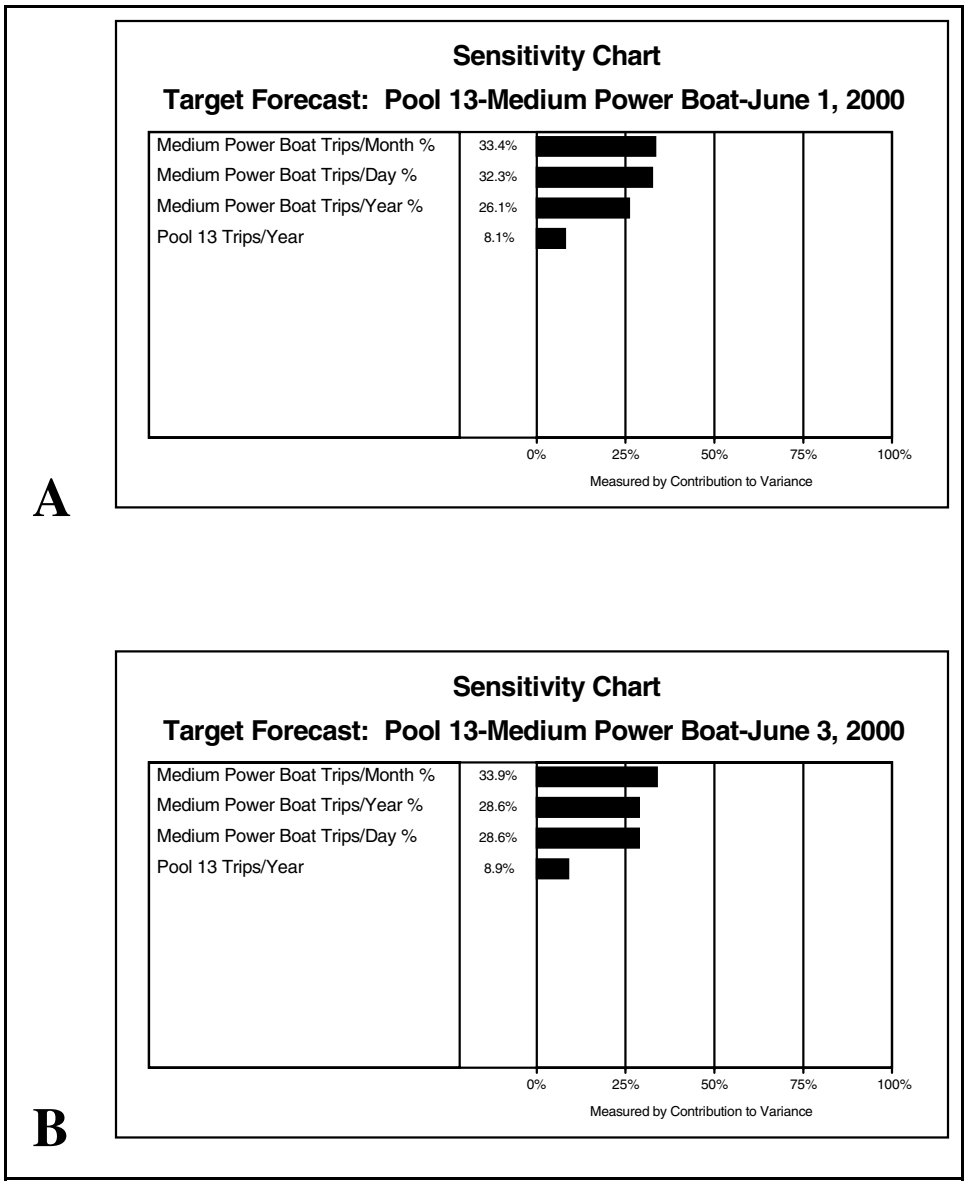

Figure 19. Sensitivity of the projected number of medium powerboats in Pool 13 for the weekday of June 1, 2000 (A), and weekend day of June 3, 2000 (B) (trips/day), to 1 percent variation on four input parameters for the recreational traffic allocation model

characterize the model parameter values. The available data are too few to permit statistical development of distributions for model parameters. Therefore, distributions were developed using the few existing data, combined with informed opinion. For parameters where only some plausible range of values could be derived from data or informed opinion, uniform distributions were developed to represent this uncertainty. In propagating such uncertainty through model projections using Monte Carlo methods, each parameter value within the range of a uniform distribution has an equal probability of being sampled and

used in the traffic allocation calculations. The uncertainty analysis distribution of the total number of annual trips per year in Pool 13 for the year 2000 was developed by using the model value of 70,922 trips/year and estimating a minimum and maximum value based on the relative error reported for the recreational trip and activity values in Region 2 (~30 percent of the mean) (USAED, St. Paul, 1993). This process was used to define a uniform distribution with a minimum value of 49,461 and a maximum value of 92,383 trips/year (Figure 20).

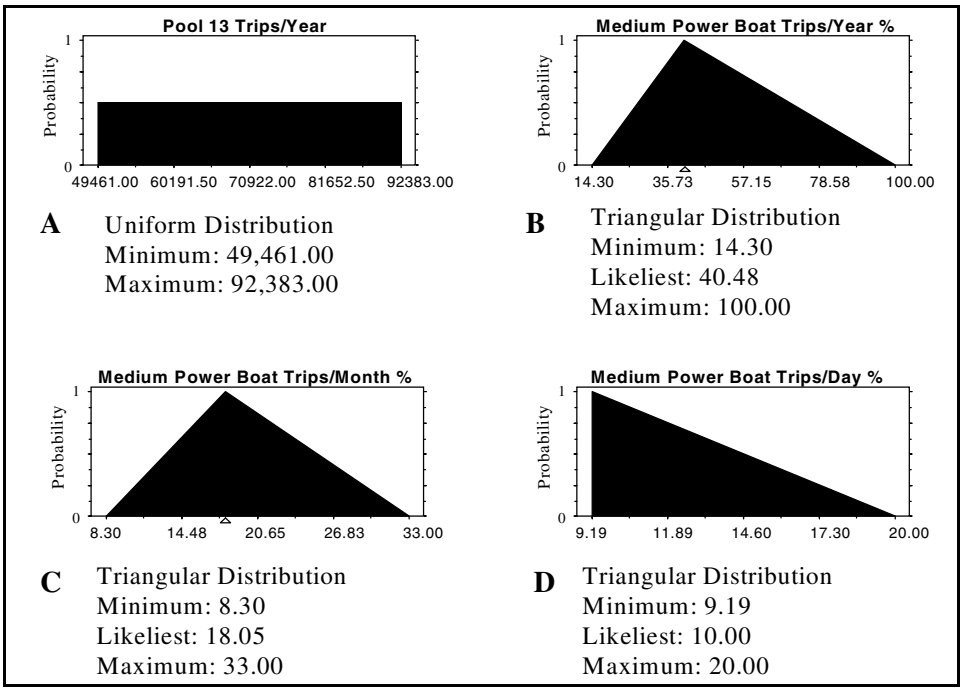

Figure 20. Descriptions of the distributions assigned to the model parameters for the uncertainty analysis for medium powerboats on June 1, 2000 (a weekday), on Pool 13[(A) trips/year 2000/Pool 13, (B) trips/year 2000/medium powerboats/Pool 13, (C) trips/year 2000/June/ medium powerboats/Pool 13, (D) trips/year 2000/June/weekday/ medium powerboats/Pool 13]

For parameters where some central tendency or modal value could be established in addition to a range of values, triangular distributions were derived to characterize this degree of parameter uncertainty. In developing a distribution for allocation of total annual trips to trips/month, the modal value for June of 18.05 percent was used to define the most likely value in a triangular distribution. If the monthly allocation was entirely random, the expected value for any month would be 1/12 or 8.3 percent. This value defined the minimum of the distribution. To determine a maximum value, it was assumed that June was one of three months (June-August) that constituted the medium powerboat season. A one-in-three chance for traffic occurring in June defined an upper value of 33 percent for this distribution (Figure 20).

A similar approach was used to define a triangular distribution for allocation of monthly traffic to specific days of the week. For weekdays (i.e., June 1), the most likely value assigned was 10 percent, while the minimum value assigned was that found in studies discussed in Chapter 3 (9.19 percent). The maximum value was defined by the chance of the vessel being in one of five weekdays, or 20 percent (Figure 20). For weekends (i.e., June 3), it was assumed that the minimum value could be defined by one of any seven days (14.3 percent); the most likely was the 25 percent value (Rust Environment & Infrastructure 1996a, 1996b), and the maximum was defined arbitrarily as 50 percent (Figure 21).

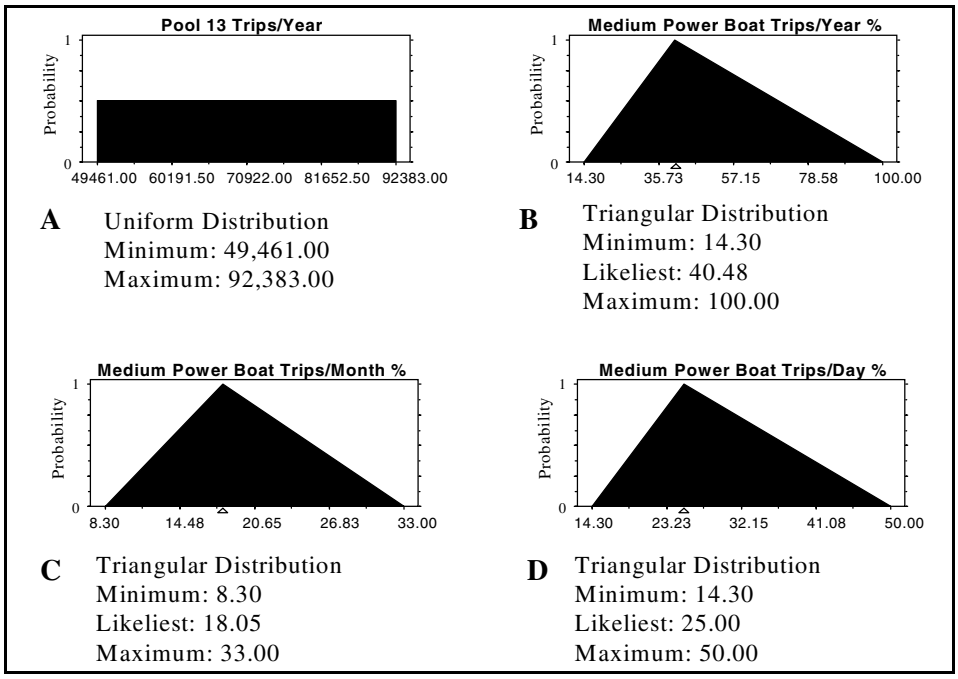

Figure 21. Descriptions of the distributions assigned to the model parameters for the uncertainty analysis for medium powerboats on June 3, 2000 (a weekend day), on Pool 13 [(A) trips/year 2000/Pool 13, (B) trips/year 2000/medium powerboats/ Pool 13, (C) trips/year 2000/June/medium powerboats/Pool 13, (D) trips/year 2000/June/ weekend day/ medium powerboats/Pool 13]

The percentage allocation of total trips/year of medium powerboats was also described using a triangular distribution. The most likely value was 40.48 based on Rust Environment & Infrastructure (1996a, 1996b); the minimum was defined by the chance of being in one of seven possible classes, 14.3 percent; and the unlikely possibility that all vessels in 2000 will be medium powerboats defined a maximum value of 100 percent (Figures 20 and 21).

Results

The results of 1,000 Monte Carlo simulations for the June 1 and June 3, 2000, forecasts are summarized as frequency distributions in Figure 22. Extrapolating

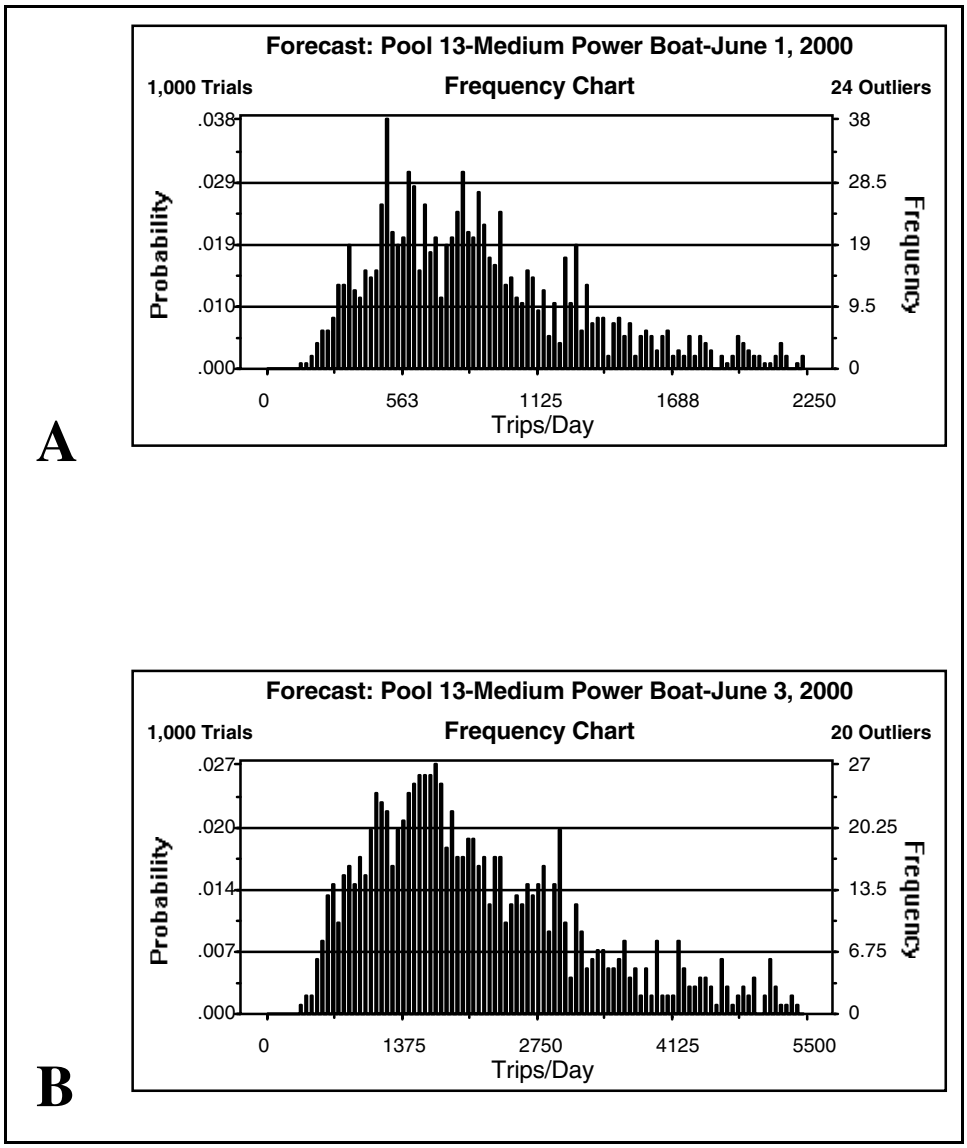

Figure 22. Frequency distributions resulting from the uncertainty analysis describing projected trips/day for medium powerboats on Pool 13 on June 1, 2000, a weekday (A) and June 3, 2000, a weekend day (B). Results are from 1,000 Monte Carlo simulations using the recreational traffic allocation model

the variability assigned to the input parameters resulted in June 1, 2000, estimates that ranged from 157 to 2,913 trips/day, with a mean value of 932 (standard deviation: 493; coefficient of variation: 0.53). The corresponding values for the June 3, 2000, forecast were a range of 354–8,728, with a mean value of 2,236 (standard deviation: 1,245; coefficient of variation: 0.56). The results of the uncertainty analysis, where parameters were varied more realistically in relation to knowledge and information, demonstrated more than one order of magnitude of variability associated with the projected numbers of future recreational traffic on the UMR-IWW System.

The relative contributions of the four input parameters were also quantified using the percent of the variance of the resulting June 1, 2000, and June 3, 2000, traffic forecasts explained by each parameter (Figure 23). The results emphasized the importance of the allocation of the total vessel trips/year to the fraction classified as medium powerboats, followed in order by the allocation to month, then allocation per day of the week. The forecast of total trips per year contributed the least amount of variance to the traffic forecasts.

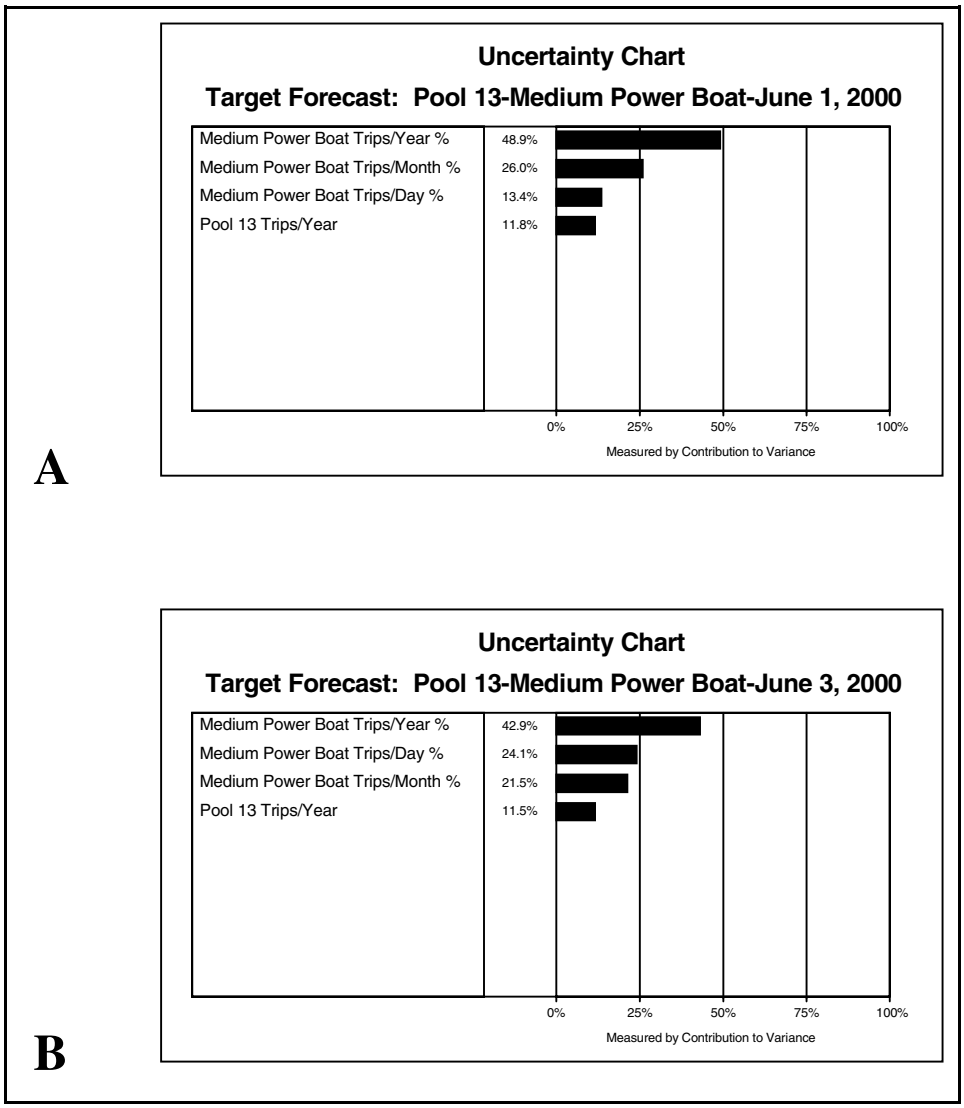

Figure 23. Uncertainty of the projected number of medium powerboats in Pool 13 for the weekday of June 1, 2000 (A), and weekend day of June 3, 2000 (B) (trips/day), to variation on four input parameters for the recreational traffic allocation model

These results are certainly dependent on the derivation of the input parameter distributions. Assigning a maximum value of 100 percent to the vessel class

allocation parameter undoubtedly emphasized the importance of this parameter in the overall traffic projections. The relatively higher precision of the estimated percentage growth of counties near Pool 13 tended to diminish the importance of the estimated total trips per year compared to the remaining parameters in the allocation model (Figure 23). Of the two remaining parameters, the allocation by month had a larger potential variability (8.3-33 percent) than the allocation to day of the week (9.19-20 percent, weekday; 14.3-50 percent, weekend day) and thus contributed more variance to the model results.

Implications

The results of the uncertainty analysis emphasized the amplification of uncertainty assigned to each input parameter in this sequence of multiplications. The overall structure of the model permits estimates of the number of vessels of each class for any day of the year on into the future. However, given the limitations on available information and data, precise estimates of future recreational traffic intensities remain difficult to project. The relative importance of new information is defined by the results summarized in Figure 23. The underlying parameter distributions (i.e., Figures 20 and 21) imply that resources might be usefully directed at improving estimates of the relative abundance of medium powerboats in the future recreational fleet. Again, this conclusion may be biased by the unlikely assumption that all boats might be medium powerboats. Thus, the upper bound of this parameter distribution appears as an important number to obtain.

Summary

The results of the sensitivity analysis reflect, in part, the simple structure of the allocation model. The results demonstrate the nearly equal importance of the percentage values of the parameters that allocate total trips/year to daily values in terms of model sensitivity under conditions where parameter values varied by ±1 percent (Figures 19a and b). The small differences in the percentage contributions of these three parameters to variability in the modeled trips/day (i.e., Figures 18a and b) might simply reflect the particular sample of values from the corresponding parameter distributions, the consistently small contribution of the total trips/year to model sensitivity resulting from the small degree of variability in this number (i.e., ±1 percent), and the fact that this variability is amplified only by each of the other three parameters in the calculation. The results of the sensitivity analysis are consistent with the simple series of calculations and are presented mainly as an example of how the approach can be used to explore the implications of the model structure as part of an overall model development process.

The uncertainty analyses demonstrate the degree of variability in projected daily trips of medium powerboats in Pool 13 for the selected days, given the current estimates of model parameters and the potential variation in these parameter estimates (Figures 22a and b). The same kind of analysis could be performed for any selected pool, day, and vessel class. The results of the

uncertainty analysis can be used to more realistically describe the expected distribution of the recreational traffic allocation model results. Distributions of traffic projections are important in terms of characterizing the overall use of the UMR-IWW System by recreational vessels and in terms of providing inputs to the assessment of potential ecological risks posed by the recreational traffic.

The results of the uncertainty analysis also emphasize the importance of accurately estimating the number of total trips/year that are classified as medium powerboats (Figures 23a and b). This parameter accounted for 43-49 percent of the variability in the estimates of trips/day in Pool 13. This importance results from the high expected values (40.48 percent) and range (14.30-100 percent) of this parameter compared to the parameters that allocate to trips/month and trips/day. These latter two parameters switch in rank-order of importance in the analysis of weekday and weekend traffic projections. Again, this results from the difference in the allocation of trips/day for the weekday (~10 percent) versus the weekend (~25 percent), compared to the monthly allocation parameters, which is ~18 percent in both analyses.

The results of these analyses can be used to rank-order the outlay of any additional resources in collecting new information to further refine the traffic projections of the model. In other words, new information and data should be collected first for the parameters that contribute the greatest amount of variation in the model results.

It is emphasized that the uncertainty analysis of this model is an iterative process. Once the vessel class allocation parameter becomes more precisely defined, the uncertainty analysis should be repeated to determine (a) the improvement in the overall precision of the model calculations, and (b) any changes in the rank-order of parameter importance. The sequence of analyzing the model and collecting the additional data identified as important should be repeated until the precision of the model calculations is sufficient to use the model reliably in making decisions concerning the numbers of different recreational vessels anticipated throughout the year for the different pools on the UMR-IWW System.

5 Additional Methods Available for Projecting Growth and Forecasting Future Recreational Traffic

The main purpose in developing the recreational traffic forecasting and allocation models was to obtain a computational tool that can be used to project future changes in traffic intensity on the UMR-IWW System. This chapter describes additional methods that are available and were considered for projecting growth and forecasting recreational traffic.

Estimated increases in recreational traffic over the period of 2000-2050 were developed using different data (e.g., statewide, regional) and assumptions, largely concerning the possible patterns of increases in human populations in the states bordering the UMR-IWW System. Several methods have been routinely used by recreational professionals to project changes in the intensity of recreational use: extension of past trends, simple regression, multiple regression, demand modeling approach, resource capacity, informed judgement, and market surveys (Walsh 1985; Ward et al. 1996).

These methods are typically applied to single sites and small geographic areas and typically rely on trend data and a number of predictive variables in order to project future use. The methods are briefly outlined in the following paragraphs, along with mention of their relative applicability to projecting UMR-IWW System recreational boating.

All of these methods are applicable in theory, if not in practice, in estimating future trends in recreational boating on the UMR-IWW System. A detailed discussion of each method lies beyond the scope of this study. It is evident that projecting future boating use on the UMR-IWW System is greatly constrained by the lack of detailed, comprehensive, historical data. However, the potential application of each method will continue to be evaluated in light of any new or existing data that might be identified in the future.

Extension of Past Trends

The extension of past trends method is a direct extrapolation of previous rates of change in recreational use to the future, in a sense, curve fitting. This method implies an assumption that the changes in future recreational use will simply follow historical patterns. The method is valid, and the results are useful as long as this assumption is not violated. Unfortunately, few, if any, trend data are available that characterize the system-level recreational trends for the UMR-IWW System. To address this limitation, existing local or regional data could be identified and compiled. Alternatively, national statistics that describe general trends in recreational use patterns could be examined. However, the relevance of these data to the UMR-IWW System cannot be easily evaluated or substantiated.

Simple Regression

This statistical method projects future recreational use levels as an empirical function of a single independent variable (usually population or total income). The function would be derived statistically by fitting data to use level and the independent variable. If the independent and dependent variables are highly correlated in the simple regression and the regression summarizes a large amount of variation in the dependent variable, the simple regression method can provide a convenient and powerful forecasting tool. It should be recognized that simple regressions can produce biased estimates if other variables that are not included in the regression are important in determining future use patterns.

Simple regression appears quite applicable to forecasting future trends in recreational use that would assist in projecting corresponding values of recreational boating via the traffic allocation model. However, as with simply extending past trends, there are few data, if any, for the UMR-IWW System to derive the necessary regression equations. This method should not be abandoned, but the necessary data will have to be identified or collected to facilitate the use of simple regression.

Multiple Regression

This statistical method projects future recreational use as a function of several independent variables. This approach is conceptually superior to the simple regression method but is more data intensive. And as with simple regression, sufficient data do not exist to develop the empirical relations between several independent variables and recreational use for the UMR-IWW System. Demand models, in the form of multiple regressions, have been developed by the U.S. Army Engineer Research and Development Center (ERDC), but these models would require significant development for application to the UMR-IWW System. Problems include limited UMR-IWW System data, the applicability of the model to multisite regions, and the ability to characterize the importance of resource substitutes in water-rich regions.

Demand Modeling Approach

The Regional Recreation Demand Models (RRDMs), developed by ERDC (Ward et al. 1996), were investigated for their potential applicability to proportioning boating use among pools and for forecasting future boating demand. The ERDC models have been used to determine the value of recreational use at several USACE reservoirs around the country. The data in these models could conceivably be applied to UMR-IWW System sites, although calibration to account for local conditions (especially multiple substitutes in water-rich regions) would be problematic in the absence of quality recreational-use data at most UMR-IWW System sites. The demand modeling approach has been abandoned as currently impractical because of the extensive data requirements and limited capabilities of this modeling approach for forecasting future traffic.

Resource Capacity

The resource capacity approach examines the physical limitations (i.e., acreage) of the resource as they might constrain increased recreational use at a particular site. The method is based on the premise that at some intensity of recreational use, physical (or functional) limitations prevent further increases in recreation at the site. Potential changes in temporal or spatial patterns of use may not be captured based on the examination of past data.

Informed Judgment

This method attempts to take advantage of the accumulated experience and informed opinion of experts in developing more subjective estimates of future trends in recreational boating on the UMR-IWW System. This method can also be used to characterize the degree of accuracy and precision (i.e., uncertainty) associated with such projections. Various means to incorporate such opinions exist, including Delphi approaches. Informed judgment has been and will be continue to be used in UMR-IWW System projections through a process of formal elicitation of river professionals. For example, the designation of low, medium, and high within-pool use areas for different recreational vessel classes resulted from a series of organized workshops that involved individuals with first-hand observations and knowledge of recreational use patterns on specific portions of the UMR-IWW System (e.g., Rust Environment & Infrastructure 1996b).

Market Surveys

Market surveys attempt to project future demand through evaluating, in this case, the recreational boating market characteristics, including trends in boat lengths, vessel types, etc. This method is complicated for the UMR-IWW System because of the size of the market area (which undoubtedly contains many

undefined submarket areas) and the long period of projection (50 years). Markets based on population growth and distance have been used to generate pool-level projections for the UMR-IWW System.

6 Limitations in Forecasting Future Recreational Boating Projections

Many unknown or poorly quantified factors may ultimately influence future recreational boating levels on the UMR-IWW System. Some of these factors refer to future conditions of the infrastructure that supports the recreational boating on these rivers, the overall environmental quality of the rivers, and adjacent public lands. Other factors include institutional conditions and social effects. These topics are briefly addressed in this chapter, along with pertinent information that has been identified during recent research efforts associated with the recreational traffic assessment.

Infrastructure and Facility Conditions

The availability of river access could be a constraining factor on the increase of recreational boating, particularly in areas that are already crowded. While some aspects of crowding are normal, physical constraints can be objectively defined, such as the availability of boat launching ramps, marina slips, and parking spaces. Many areas are already believed to be at or near their physical capacity during peak use periods, and the added pressure of growing demand would only worsen these situations. Boaters may respond to areas that are at full capacity by waiting, by seeking an alternate area, by choosing a less crowded time, or by boating less often. Each response would affect the accuracy of projections produced by the recreational traffic forecasting and allocation models.

The quality of the facilities may also change through time, depending on maintenance. Increasing the size or number of facilities is a possibility, although a number of factors suggest that this is not an outcome that can be expected automatically, given the limited budgets of providing agencies and the concern that many areas are already too crowded.

The actual surface water area available for boating may also determine boating constraints. The density of craft (measured as active craft per acre) was

considered high in many zones along the St. Croix River (8 of 13 zones) and in several zones along the UMR-IWW System based on aerial observations (Macbeth 1996). While objective measures of such crowding are difficult due to localized conditions, increased use may be affected by surface crowding.

Environmental Resource Quality

The natural quality of the river resource has direct effects on the quality of visitor experiences. Water quality, the number and types of fish available, and other natural attributes that affect recreational quality change through time and cannot be accurately predicted. Continued siltation may reduce access to areas currently used by boaters, especially in the river backwaters. The extent to which these areas will be maintained through dredging or other means is unknown.

The environmental quality of the resource was mentioned as the most important management issue by UMR-IWW System boaters (Carlson et al. 1995) and by the general public in the states bordering the UMR-IWW System (Carlson 1997). Boaters commonly mentioned that they choose areas to go boating based on aesthetic appeal, convenient location, and the quality of hunting and fishing. However, while many people believe the water quality continues to worsen (contrary to the findings of most water quality studies), recreational use has increased, suggesting that the relationship between perceived resource quality and amount of use is complex.

Social and Institutional Conditions

There is a great deal of uncertainty in anticipating the behavior of individuals and organizations that will be involved in recreational boating in the future. Preferences and tastes of individuals may change, along with their standards of living. Institutional budgets and priorities cannot be forecast. In a recent survey of the general public, improvements to recreational facilities received lower support than efforts to improve water quality, restore habitat, and reduce potential flood damage (Carlson 1997). Relative priorities within society are established politically. The importance of public opinion in shaping policy and how opinions might change through time are largely unknown.

Social Effects

Recreational boaters create social impacts among boaters, persons engaging in other types of recreation on the river, and riparian residents. In addition, recreation researchers have conceptualized the existence of a social carrying capacity that describes an intensity of recreational use that an area can withstand while sustaining a recreational experience of acceptable quality (Graefe, Vaske, and Kuss 1984). As the concept of social carrying capacity has developed, it has become evident that there is not a unique level that meets this criterion, but instead a range of values that relate to the conditions desired for an area. The

types of conditions desired and the normal expectations held by recreationists vary across settings, activities, groups, and individuals.

Visitor satisfaction is a consistently stated goal of recreation managers. Satisfaction is influenced by resource setting factors (i.e., water quality, desirability of facilities, or the amount of litter) and behavioral factors (perceived crowding, ability to attain goals, etc.) (Herrick and McDonald 1992). While much of outdoor recreational literature has focused on wilderness recreation, and most river studies have focused on whitewater experiences, studies of urban river recreationists show that they share similar basic motivations. The top five reasons for visiting an urban river corridor are sought by outdoor recreationists everywhere (Robertson 1989): (a) a departure from urban pressures, (b) a return to nature, (c) natural scenic qualities, (d) opportunities for privacy and solitude, and (e) a safe environment.

The number of recreationists and the types of activities in which they engage are key factors in determining satisfaction. Given the range of recreational uses on the river system, the potential for conflict among users seems inevitable. Conflict results when individuals with contrasting standards of behavior (i.e., personal norms) interact. Such differences in personal standards may exist among participants engaged in the same activity, as well as among people participating in different activities (Graefe, Vaske, and Kuss 1984). In an overview of the literature, Graefe, Vaske, and Kuss (1984) have characterized certain types of recreationists as sensitive or tolerant. Nature and solitude seekers are considered sensitive, as are paddling canoeists, fishermen, frequent participants, and specialized or experienced visitors. Tolerant user groups include thrill seekers, motor boaters, nonfishing water-related sports, infrequent participants, and generalist or inexperienced visitors. Boaters in one study were found to have varying norms of tolerance for most behaviors and encounters, with the exception of three zero-tolerance norms: discourteous behavior, human waste, and jet boat encounters for nonjet boaters (Whittaker and Shelby 1988). The three highest problem behaviors identified by riparian landowners on the St. Croix River were technology related: speeding boats, noisy jet skis, and loud boat engines (Thompson, Lime, and Lewis 1996). Not surprisingly, a smaller percentage of boaters viewed these behaviors as problematic (Dalton et al. 1996).

Researchers expect recreationists who encounter situations inconsistent with their expectations to react through displacement (seeking the same experience elsewhere or not at all) or product shift (altering their expectations to cope with the conditions encountered) (Shelby, Bregenzer, and Johnson 1988). These concepts have been fairly difficult to document and measure, in large part because recreationists voluntarily select their locations, and dissatisfied visitors will not likely be found at sites. This can result in only satisfied visitors being encountered. However, in a study designed to capture intrasite movement, boaters dissatisfied with the level of crowding on the St. Croix River were documented shifting use to nearby stretches of the Mississippi River (Becker 1981).

Managers face the difficult problem of having to identify which types of user groups should be favored. In the absence of such decisions, however, Graefe, Vaske, and Kuss (1984) note that it is important to recognize that this judgment is inherent to the carrying capacity question and will occur by default if not deliberately introduced. Avoidance of a specific experience essentially allows those activities that can preempt other opportunities to determine the recreational character of the areas (Graefe, Vaske, and Kuss 1984).

7 Recreational Fleet Characteristics

The recreational traffic allocation model, despite its limitations and uncertainties, provides estimates of future numbers of different types of recreational vessels that might be encountered throughout the UMR-IWW System. Physical dimensions of boat length, width, horsepower, propeller revolutions per minute (rpm), and speed are useful characteristics for estimating the forces associated with commercial traffic (i.e., Maynord 1999). Data describing current velocities, shear stresses, wake waves, and water volumes entrained through propellers associated with recreational vessels have been identified as a result of a literature review. These physical forces, in combination with the recreational traffic allocation model, will be used to estimate the ecological effects associated with recreational traffic.

Vessel Lengths

While an inventory of boats that use the UMR-IWW System does not exist, some information about the composition of the boat fleet is available. The Wisconsin Recreational Boating Survey documented that boats using the Mississippi River averaged 5.43 m (17.8 ft), compared with the statewide average of 4.9 m (16.0 ft) (Penaloza 1991). Results from the Economic Impacts of Recreation Study show an average of approximately 4.9 m (16 ft) for boats launched at ramps and from private docks; marina craft average 8.29 m (27.2 ft) (Carlson et al. 1995). Comparable figures were reported in a study of Pools 7 and 8 (Vogel, Titre, and Chilman 1996). The distribution of boats by length and by access type from the Economic Impacts of Recreation Study is shown in Figure 24 (Carlson et al. 1995).

The distribution of craft that use the UMR-IWW System presented in Figure 24 does not indicate the amount of time that the boats are active on the water. The amount of time active on the water is a key component in estimating the effects on the resource. To gather information about active boats, field observations were conducted in 1996 to determine the type and speed of active recreational boats at eight locations on the UMR-IWW System (Rust Environment & Infrastructure 1996b). The observations were made during

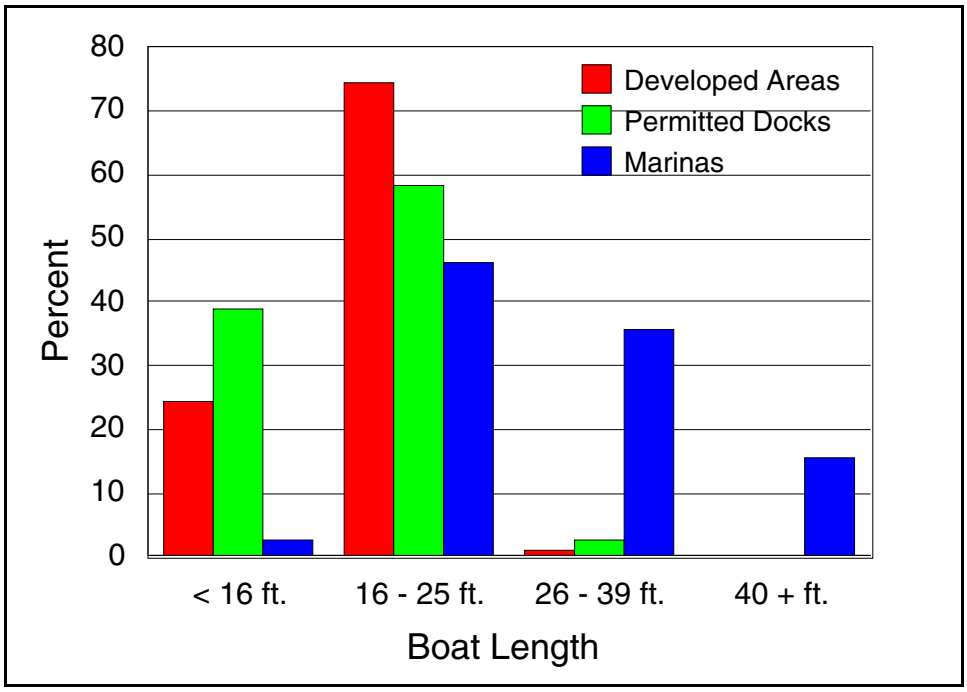

Figure 24. The distribution of recreational boats by length for each access type (from Carlson et al. 1995) (to convert boat lengths to meters, multiply by 0.3048)

high-use periods to capture samples large enough to be worthwhile. The results of the distribution of boats by type for four sampling locations on the UMR-IWW System during the summer of 1996 are presented as an example (Figure 25).

The results of the 1996 field observations (Rust Environment & Infrastructure 1996b) indicated that sailboats were on average 7.3 m (24 ft) long, and jet skis averaged 2.4 m (8 ft) in length (Table 6). Fishing boats were 5.2 m (17 ft) long on average (Table 6). Average length of medium powerboats was 6.4 m (21 ft); large cruisers averaged 8.5 m (28 ft) in length; and average pontoon boats were 7 m (23 ft) long (Table 6). Finally, the average length of houseboats was 9.8 m (32 ft) (Table 6).

Vessel Speeds

Results of the 1996 survey (Rust Environment & Infrastructure 1996b) provided data that describe vessel speeds for different classes of recreational boats (Table 7). Top speeds observed for various vessel classes in the survey are presented in Table 7. Vessels at anchor, recorded at idle, or in no-wake zones were not included in calculation of average speeds. Sailboats moved 14 km/hr (9 mph) on average, while jet skis averaged a speed of 45 km/hr (28 mph). Average speed for fishing boats was 34 km/hr (21 mph); medium powerboats traveled 40 km/hr (25 mph) on average; and large cruiser speed averaged

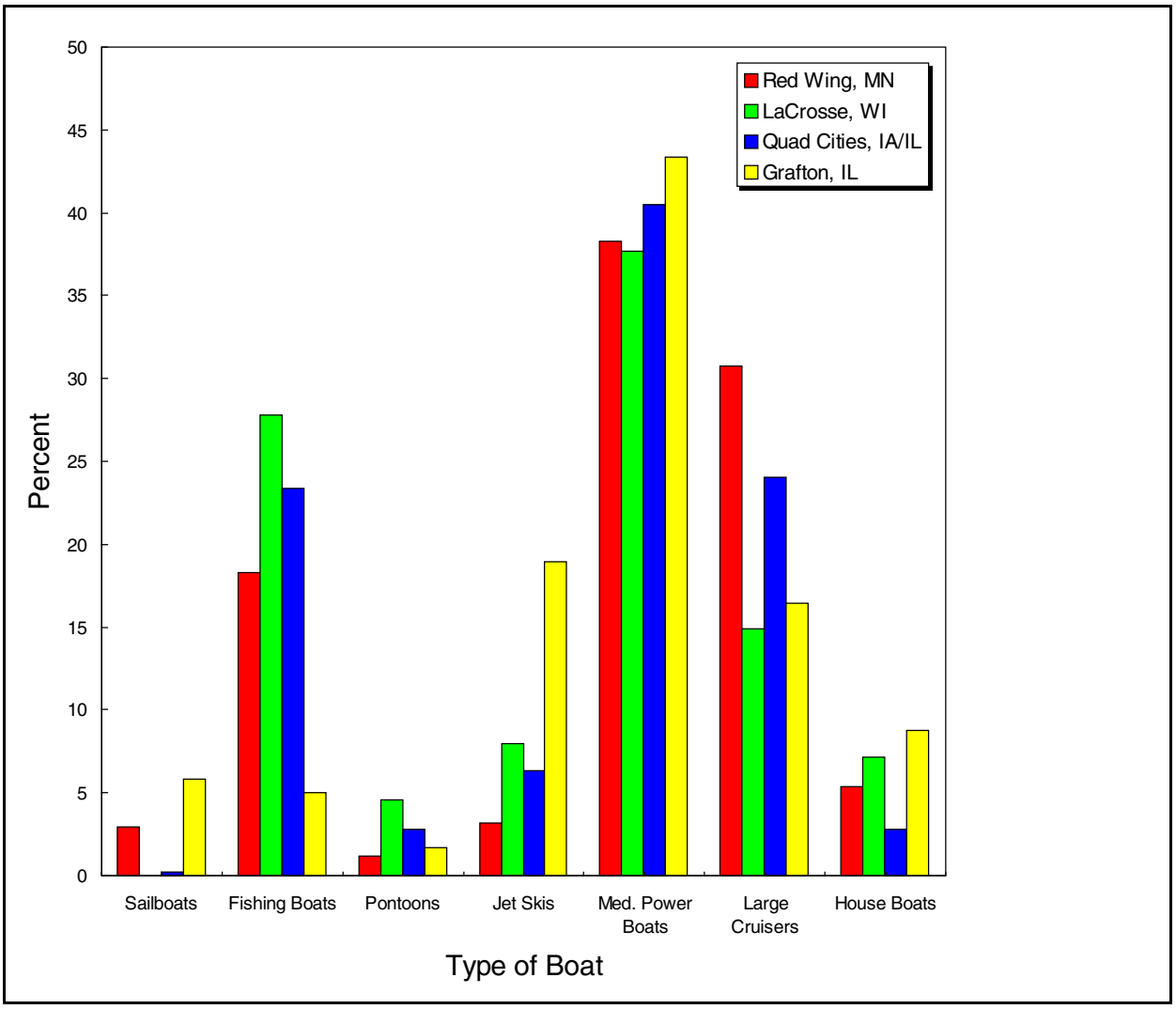

Figure 25. Recreational boat observations on the UMR-IWW System, summer 1996 (from Rust Environment & Infrastructure 1996b)

37 km/hr (23 mph). Pontoon boats cruised at an average speed of 23 km/hr (14 mph), while houseboats moved at 19 km/hr (12 mph) on average.

Propeller Diameters

Propeller characteristics of each vessel type are presented in Table 8. Since jet skis do not operate by propeller, they are excluded from this table. Propeller diameters are similar for fishing boats and pontoon boats. Large cruisers and houseboats also have similar propeller diameters. Propeller pitches are similar for medium powerboats and houseboats but different for the rest of the vessel classes. Propeller pitch refers to the angle of the propeller blade. For example, the 381-mm (15-in.) pitch for a fishing boat indicates that with each propeller revolution, the boat theoretically would advance 381 mm (15 in.). Propeller slip,

Table 6
Statistics on Vessel Length, ft, for Recreational Traffic in the UMR-IWW System (Rust Environment & Infrastructure 1996b)

Vessel Type	Mean Length[1]	Standard Deviation	Minimum	Maximum
Sailboats	24	4	15	32
Jet Skis	8	1	7	21
Fishing Boats	17	2	8	24
Medium Powerboats	21	3	10	34
Large Cruisers	28	2	16	48
Pontoon Boats	23	2	16	28
Houseboats	32	8	15	60

[1] To convert mean length to meters, multiply by 0.3048.

Table 7
Statistics on Vessel Speed, mph, for Recreational Traffic in the UMR-IWW System (Rust Environment & Infrastructure 1996b)

Vessel Type	Mean Speed[1]	Standard Deviation	Minimum	Maximum
Sailboats	9	3	4	15
Jet Skis	28	9	4	50
Fishing Boats	21	10	0	61
Medium Powerboats	25	9	2	64
Large Cruisers	23	9	2	59
Pontoon Boats	14	6	3	29
Houseboats	12	5	3	32

[1] To convert mean speed to kilometers per hour, multiply by 1.609.

Table 8
Typical Propeller Characteristics of Each Vessel Type (Gerr 1989; Michigan Wheel, Inc., personal communication)

Vessel Type	Typical Power horsepower[1]	Typical Propeller Diameter [2], in.	Typical Propeller Pitch [2] in.	Typical Propeller Slip
Fishing Boats	50, outboard	12.25	15	0.30
Pontoon Boats	50, outboard	13	11	0.35
Medium Powerboats	100-300, inboard/outboard	14	19	0.26
Large Cruisers	200-500, inboard	17	17	0.28
Houseboats	2-100 to 300, inboard/outboard	17	19	0.43

[1] To convert horsepower to watts, multiply by 745.7.
[2] To convert inches to millimeters, multiply by 25.4.

which is different for each of the vessel classes, is a measure of how efficiently the boat is going through the water. If the propeller did not slip at all as it churned through the water, each revolution would theoretically propel the boat forward at a distance equal to the propeller pitch. However, due to propeller slip, the boat actually goes slower than the theoretical speed, normally around 10-20 percent slower at top speed. The lowest propeller slip is for medium power-boats, while the highest slip occurs in houseboats.

Distributions of Trip Lengths

The duration of boating trips and the amount of time boats are active on the water have been measured in several studies on the UMR-IWW System. The length of trips consistently averages about 5 hours per trip. A study of Pools 7 and 8 resulted in averages of 4.7 hours for trips originating at boat ramps and boat docks and 5.7 hours for marina trips (Vogel, Titre, and Chilman 1996). Trip lengths reported in a study of Pool 24 averaged 4.2 hours (Farabee 1993). In addition, a statewide boating study in Wisconsin reported average trip lengths of 5.4 hours (Penaloza 1991).

The amount of time boats are active on the water was even more consistent across studies, averaging about 60 percent. Results from the Pools 7 and 8 study fall between 53 percent and 57 percent across access classes (Vogel, Titre, and Chilman 1996). A Minnesota study of lake and river boating reported active time at 60 percent (MNDNR 1997). The MWBAC's Recreational Boating Studies report an active time between 55 and 64 percent across various study years (Macbeth 1995).

By combining the information described in the previous paragraphs, an average boat trip involves active time on the water of about 3 hours.

Distributions available from several of these studies have been used to describe the uncertainty relationships around the mean of 3 hours.

Location Within-Pool or Within-Pool Daily Use by Vessel Class

The recreational traffic allocation model currently predicts daily trips for each recreational vessel class within each pool on the UMR-IWW System. However, in order to estimate the ecological effects associated with each recreational vessel class, daily use patterns by each recreational vessel class within each pool on the UMR-IWW System will ultimately be predicted (Figure 3). To achieve this degree of spatial-temporal resolution, the daily use estimates for each pool and vessel class will be integrated with a Navigated Areas GIS Database that defines within-pool areas of low, medium, and high traffic density for each category of recreational vessels. The Navigated Areas GIS Database was created as a result of numerous workshops (Rust Environment & Infrastructure 1996a). During these workshops, maps of recreation vessel data (high, medium, and low use for each vessel class) for UMR Pools 2 through 6, 9 through 22, 24 through 26, the open Mississippi River, and the IWW Peoria Pool were prepared. These maps generated by a GIS serve as the baseline and have been given to ERDC; these base maps will be used to generate maps illustrating the spatial distribution and intensity of forecasted recreational boating traffic in the UMR-IWW System. Within-pool trips per day for each vessel class will be further subdivided and apportioned among specific areas with each pool; the results for Pool 8 are included in Appendix D as an example. This final allocation represents the highest resolution in the recreational traffic model; it is the last step in the modeling process for characterizing the baseline recreational traffic on the UMR-IWW System.

Assumptions

Several important assumptions underlie this component of the allocation process. First, it is assumed that the spatial location and extent of the survey data developed to quantify within-pool use are representative of the entire UMR-IWW System. Second, assumptions have been made concerning the numerical translation of the categories of low, medium, and high to numerical estimates of trips per day. Relating the number of future trips per day to low, medium, and high density will be done on a pool-by-pool basis. Third, it is assumed that the within-pool locations of low, medium, and high traffic will remain unchanged during the project period (2000-2050).

Uncertainties

The potential bias and imprecision associated with the within-pool daily use by vessel class projections derive principally from the nature of the process used to estimate these numbers. Informed opinions were solicited from experienced individuals with a working knowledge of recreational traffic patterns on selected pools. These individuals basically mapped areas within pools using their best

estimates of high, medium, and low densities of the different recreational vessel classes. These hand-drawn maps were transformed to GIS data coverages for integration with the pool-specific estimates of daily use by recreational vessels. Thus, the quality of the projections depends on the number of participating individuals in combination with their accuracy and precision in characterizing recreational traffic on the UMR-IWW System.

Projected Growth in Boat Ownership by Size

The trend in national boat fleet characteristics is toward bigger boats (Figure 26). The historical shift in the U.S. market share has been from boats less than 5 m (16 ft) (66 percent of total in 1970; 50 percent in 1991) to boats in the 5- to 8-m (16- to 25-ft) class (31 percent of total in 1970; 46 percent in 1991) with boats larger than 8 m (26 ft) holding a steady share around 4 percent (MNDNR 1993). The market share for boats less than 5 m (16 ft) is projected to drop to 43 percent by the year 2000, with boats in the 5- to 8-m (16- to 25-ft) class increasing to 53 percent.

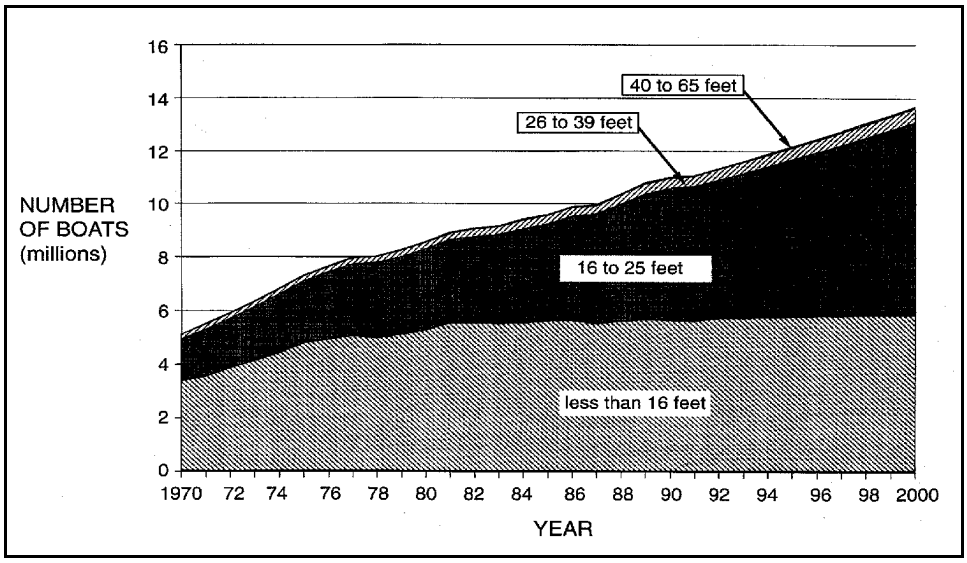

Figure 26. Projection of nationwide registered boats by length 1992 to 2000 (from MNDNR 1993) (to convert lengths to meters, multiply by 0.3048)

These trends have been noted in observations for the biennial aerial surveys of active boats on the UMR-IWW System (Macbeth 1996). Since 1989, a drop in fishing boats and a substantial increase in the number of cruisers have been observed. While less reliable than boating registration data, these observations are more pertinent to assessing impacts to the resource since they reflect amount of time active on the water.

The trend toward bigger boats over time is not addressed in the recreational traffic allocation model. Instead, the trend toward increasing boat size will be addressed within each vessel class when calculating the associated physical forces that will be used to estimate the ecological effects.

8 Summary and Recommendations

This report presents recreational traffic forecasting and allocation models that estimate daily use for seven classes of recreational boats within pools on the UMR-IWW System for the period 2000-2050. The models were developed in support of the UMR-IWW System Navigation Study to assess the potential ecological risks posed by recreational traffic to submerged rooted aquatic plants, freshwater mussels, and fish inhabiting the UMR-IWW System. Model results will also be used to address the potential for increased bank erosion. The report demonstrates that it is possible to construct forecasting and allocation models, as well as to use the allocation model to examine the implications of accuracy and precision in the model.

The results of the initial simulations of the recreational traffic forecasting and allocation models suggest several recommendations for future model refinement and implementation:

a. The projections of pool-specific trips/day for each vessel class are determined primarily by the poolwide forecast of total annual trips for all recreational boats. Refinement in model projections requires additional effort in accurately and precisely estimating this number.

b. The potentially large number (>4 million) of possible model projections precludes a comprehensive sensitivity and uncertainty analysis of the allocation model. This magnitude of model output also requires consideration given to selecting and specifying model projections for generation of tables, graphs, and other visual summarizations of the model results.

c. The large number of possible outputs of interest argues for some effort aimed at identifying particular combinations of vessel type, use pattern, and ecological resource distribution that suggest unacceptable risks for plants, mussels, fish, and increased bank erosion. These combinations can then become the focus of more detailed analysis, including the characterization of model sensitivity and uncertainty.

d. Following from the second and third recommendations, spatial-temporal scales appropriate for assessing ecological risks to plants, freshwater mussels, fish, and increased bank erosion in relation to physical forces generated by recreational traffic should be used to define the corresponding scales for traffic projections made using the allocation model.

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13. ABSTRACT *(Maximum 200 words)*

This report describes recreational traffic forecasting and allocation models developed to estimate future increases in recreational boating on the Upper Mississippi River-Illinois Waterway (UMR-IWW) System. The forecasting model calculates the total number of boating trips for each pool from 2000 through 2050. The allocation model partitions results of the forecasting model to the number of anticipated trips per day for seven classes of recreational vessels for each pool. Methods of sensitivity and uncertainty analyses were used to examine the variation in estimates of boating activity in relation to uncertainty associated with model parameter values. The allocation model will be linked to a database developed to describe within-pool distributions of vessel types. Changes in physical forces generated by recreational vessels will be calculated to estimate the potential impacts of increased recreational boating on ecological resources. The risk assessment methodology and results will be presented in a future report. The potential impacts of projected increases in commercial traffic on ecological resources are being evaluated as part of the UMR-IWW System Navigation Study. The assessment of ecological risks posed by recreational traffic can provide a useful context for evaluating the significance of potential ecological risks posed by commercial traffic on the UMR-IWW System.

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