The Navigation Economic Technologies Program

March 16, 2006

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ANALYSIS OF TOWBOAT OPERATING AREAS

US Army Corps of Engineers®

IWR Report 06-NETS-R-04

Navigation Economic Technologies

The purpose of the Navigation Economic Technologies (NETS) research program is to develop a standardized and defensible suite of economic tools for navigation improvement evaluation. NETS addresses specific navigation economic evaluation and modeling issues that have been raised inside and outside the Corps and is responsive to our commitment to develop and use peer-reviewed tools, techniques and procedures as expressed in the Civil Works strategic plan. The new tools and techniques developed by the NETS research program are to be based on 1) reviews of economic theory, 2) current practices across the Corps (and elsewhere), 3) data needs and availability, and 4) peer recommendations.

The NETS research program has two focus points: expansion of the body of knowledge about the economics underlying uses of the waterways; and creation of a toolbox of practical planning models, methods and techniques that can be applied to a variety of situations.

Expanding the Body of Knowledge

NETS will strive to expand the available body of knowledge about core concepts underlying navigation economic models through the development of scientific papers and reports. For example, NETS will explore how the economic benefits of building new navigation projects are affected by market conditions and/or changes in shipper behaviors, particularly decisions to switch to non-water modes of transportation. The results of such studies will help Corps planners determine whether their economic models are based on realistic premises.

Creating a Planning Toolbox

The NETS research program will develop a series of practical tools and techniques that can be used by Corps navigation planners. The centerpiece of these efforts will be a suite of simulation models. The suite will include models for forecasting international and domestic traffic flows and how they may change with project improvements. It will also include a regional traffic routing model that identifies the annual quantities from each origin and the routes used to satisfy the forecasted demand at each destination. Finally, the suite will include a microscopic event model that generates and routes individual shipments through a system from commodity origin to destination to evaluate non-structural and reliability based measures.

This suite of economic models will enable Corps planners across the country to develop consistent, accurate, useful and comparable analyses regarding the likely impact of changes to navigation infrastructure or systems.

NETS research has been accomplished by a team of academicians, contractors and Corps employees in consultation with other Federal agencies, including the US DOT and USDA; and the Corps Planning Centers of Expertise for Inland and Deep Draft Navigation.

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ANALYSIS OF TOWBOAT OPERATING AREAS

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Final Report Prepared for the Institute for Water Resources (IWR)

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March 16, 2006

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EXECUTIVE SUMMARY

Towboats migrate to the Upper Mississippi River (UMR) during the early spring and out of it in late fall; thus, seasonal variation in the system use would be significant and also affect other river basins. Therefore, it should be noted that serious distortions could result in analyzing this waterway system unless we take such seasonal fluctuations into account.

According to several studies on UMR lock operation *(1-3)*, the seasonality is driven not only by the UMR's physical operating conditions (freezing during winter) but also by the seasonal variation in demand (e.g., grains and coal shipments). Among these, Sweeney (2004) and Center for Transportation Studies (CTS) at the University of Missouri–St. Louis (2005), which largely motivated the present analysis, indicate that towboats which choose to operate on the UMR system during the peak period move outside that system and operate during the winter because they can thus earn greater profit. Those studies suggest that the towboats are always busy. However, it should be noted that some towboats may not operate during the winter due either to lack of demand or the freezing the UMR. In order to identify the fraction of the towboats that continue to operate during the winter and their winter operation areas, (i) three distinct UMR time frames are specified based on its monthly towboat traffic; peak (April through November), off-peak (January and February), and transition periods (December and March). In addition, (ii) we determine the unique towboats that contribute most UMR towboat lockages during the peak and (iii) try to track them during the off-peak.

The tracking results during the winter for every unique towboat in the 90% group as well as lock use by towboats throughout the study area are the main outputs of the analysis. However, it should be noted that the tracking results may miss some vessels that operate without passing through locks since they depend on lock data (OMNI for 2000-2004) from the U.S. Army Corps of Engineers. The study area of this analysis includes all divisions of the U.S. waterway system to which the towboats serving the UMR can realistically shift in winters.

It is found that during the UMR off-peak towboats hardly operate upstream of UMR Lock #25 and decrease their operation significantly in the segment bounded by UMR Locks #26 and #27. In addition, towboat lockages at the lower Illinois (IL) locks (#07 and #08) increase during the UMR off-peak due to towboats shifting from the UMR. Ohio (OH) towboat lockages decrease slightly during the UMR off-peak; however, towboats shifting from the UMR to Ohio during the off-peak have more Ohio lockages than those generated by towboats shifting during the peak. Finally, it seems that the UMR seasonality affects mostly the Illinois, Ohio and the UMR itself. Detailed results are summarized in the conclusions of this report. These results are intended to support the development of the NASS navigation simulation model and help improve the effectiveness of the U.S. inland waterways.

1. INTRODUCTION

The Upper Mississippi River (UMR), which has 29 lock and dam facilities along it, carries a large fraction of the cargo moving on the U.S. inland waterways. It periodically experiences severe congestion (particularly at the lower UMR locks) due to seasonal variations in system use as well as to the relatively short (600 ft) lock chambers provided at most locks. Many towboats now exceed the 600 ft length and require relatively slow double cut lockages. According to Sweeney (2004) and the UMSL Center for Transportation Studies (CTS) (2005), the UMR seasonality is evident because the operating conditions become extremely difficult or impossible in winter due to the freezing of the river and demand (e.g., grains and coal shipments) is seasonal as well. Many towboats migrate to the UMR during the early spring and out of it in late fall; cyclic influx and efflux of towboats to the UMR has been observed in the previous studies *(1-3)*. The objective of this analysis is to understand characteristics of the UMR towboat operation and provide practical information about towboat use in the study area for the UMR navigation system simulation (NaSS) model, which is being developed by the U.S. Army Corps of Engineers. Some obvious questions that provide the major impetus for this analysis are listed below.

- *When are the peak and off-peak seasons for the UMR towboat operation?*
- *What fractions of the towboats that normally operate on the UMR in summers continue to operate during in winters?*
- *Where else (if anywhere) do they go?*
- *What is the impact of the UMR seasonality on the other river systems?*

We hope the answer to the questions will help support the development of the NaSS model by identifying seasonal operating patterns and interactions among various rivers; furthermore, the analysis procedures presented in this study should help in developing demand and equipment assignment inputs for simulating waterways. Table 1 presents the analytic tasks conducted in this study to resolve the questions. The study area, data, and definition of towboat lockages required for the analytic tasks are illustrated in the next sections.

Table 1. Analytic Tasks for Identifying the Impact of the UMR Seasonality

Task 1	Identify seasonal variation of towboat lockages at the UMR system over 12 months
Task 2	Determine the departing and entering periods of the towboats to the UMR system
Task 3	Identify the number and IDs of unique towboats required to account for most (90%) UMR towboat lockages during non-freezing condition
Task 4	Determine the state of the unique towboats during the winter (whether they continue to use locks or not and where they operate)
Task 5	Compare total towboat lockages and the lockages attributable to the unique towboats

2. ANALYTIC APPROACH

2.1. Study Area

The study area of this analysis includes all divisions of the U.S. waterway system in which the towboats serving the UMR locks can realistically operate. The Pacific Ocean Division (POD) is excluded in the study area since towboats are assumed to stay on inland waterways. Figure 1 shows districts in the study area by divisions. The official symbol and Engineer Reporting Organization Code (EROC) of each district in the study area are shown in Table 2.

Table 2. Districts in the Study Area

Name	Official Symbol	EROC
Mississippi Valley Division	MVD	B0
St. Paul District	MVP	B6
Rock Island District	MVR	B5
St. Louis District	MVS	B3
Memphis District	MVM	B1
Vicksburg District	MVK	B4
New Orleans District	MVN	B2
Great Lakes & Ohio River Division	LRD	H0
Huntington District	LRH	H1
Louisville District	LRL	H2
Nashville District	LRN	H3
Pittsburgh District	LRP	H4
Buffalo District	LRB	H5
Chicago District	LRC	H6
Detroit District	LRE	H7
North Atlantic Division	NAD	E0
Baltimore District	NAB	E1
New York District	NAN	E3
Norfolk District	NAO	E4
Philadelphia District	NAP	E5
New England District	NAE	E6
Southwestern Division	SWD	M0
Fort Worth District	SWF	M2
Galveston District	SWG	M3
Little Rock District	SWL	M4
Tulsa District	SWT	M5
South Atlantic Division	SAD	K0
Charleston District	SAC	K2
Jacksonville District	SAJ	K3
Mobile District	SAM	K5
Savannah District	SAS	K6
Wilmington District	SAW	K7
Northwestern Division	NWD	G0
Portland District	NWP	G2
Seattle District	NWS	G3
Walla Walla District	NWW	G4
Kansas City District	NWK	G5
Omaha District	NWO	G6
South Pacific Division	SPD	L0
Los Angeles District	SPL	L1
Sacramento District	SPK	L2
San Francisco District	SPN	L3
Albuquerque District	SPA	L4

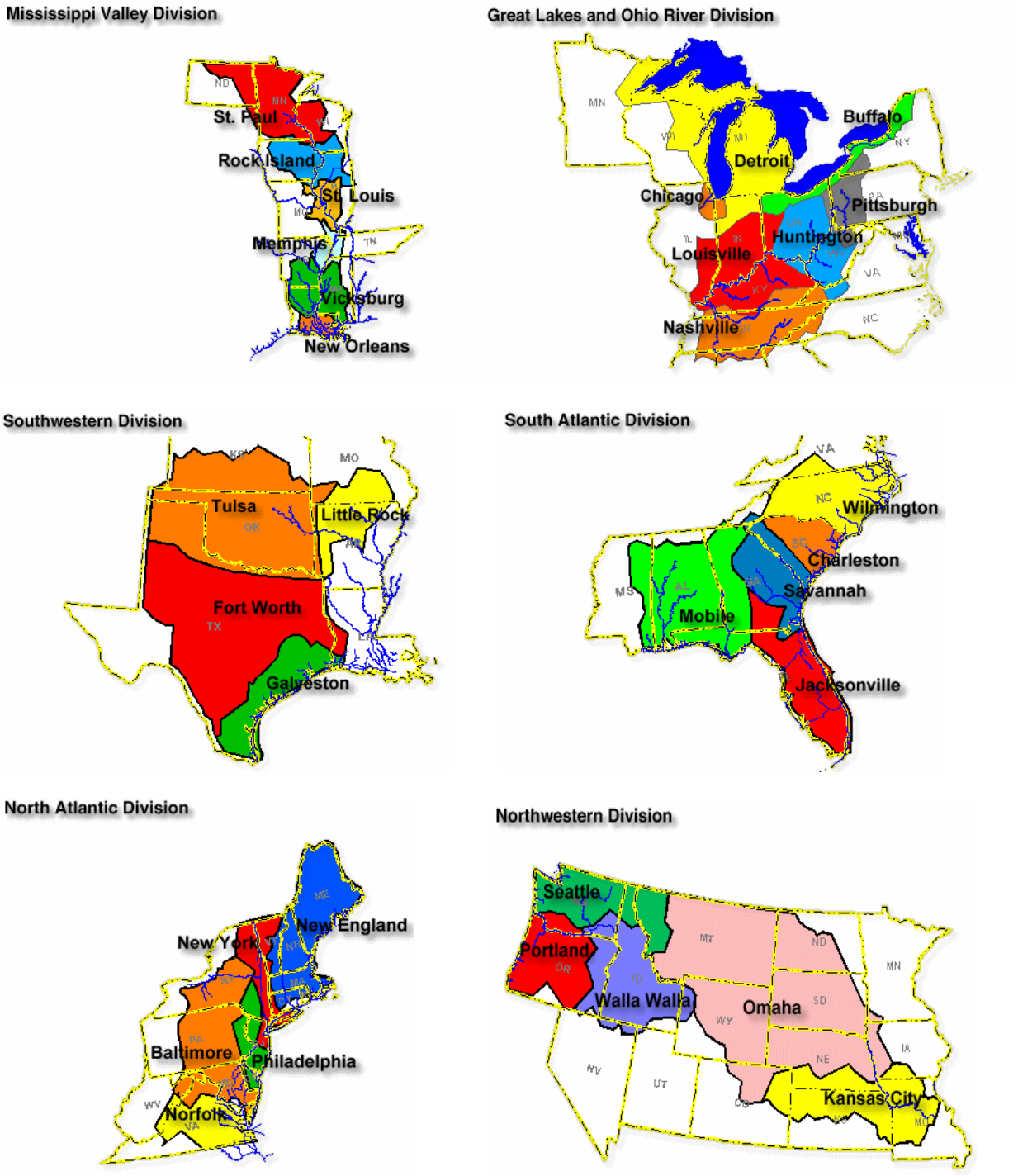


Figure 1. Study Area[1]

[1] Figures are quoted from the Navigation Data Center of the U.S. Army Corps of Engineers

In the current inland waterway system, locks are critical data-collection points at which various kinds of information about vessel movements are recorded, including unique ID, start and end of lockage time and travel direction of the vessel. Our analysis track vessels movements based on the information recorded at locks. Table 3 shows the locks on various rivers in the districts of the study area. Many districts in the study area (e.g., all districts in the South Pacific Division (SPD) and Memphis (MVM), Baltimore (NAB), Philadelphia (NAP), New England (NAE), Fort Worth (SWF), Charleston (SAC), Kansas City (NWK), and Omaha (NWO) districts) have no locks on their rivers. Most locks in Table 3 are shown in Figures 2 and 3; however, some locks shaded in the table are not presented in the figures since towboat lockages are never observed in such areas. It is noted that the unique lock numbers presented in Figure 3 (rather than the lock names) are used throughout this report.

Table 3. Locks in the Study Area

Division	District (EROC)	River (Code)	# of Locks	Names of Lock
MVD	MVP (B6)	Mississippi River (MI)	13	1, 2, 3, 4, 5, 5A, 6, 7, 8, 9, 10, Upper St. Anthony Falls, Lower St. Anthony Falls
	MVR (B5)	Illinois River (IL)	8	Lagrange, Peoria, Starved Rock, Marseilles, Dresden Island, Brandon Road, Lockport, Thomas J. O'Brien
		Mississippi River (MI)	12	11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22
	MVS (B3)	Kaskaskia River (KS)	1	Kaskaskia
		Mississippi River (MI)	4	24, 25, 26 (Melvin Price), 27
	MVK (B4)	Ouachita and Black Rivers (OB)	6	Jonesville, Columbia, Felsenthal, H.K. Thatcher, 6, 8
		Red River (RR)	5	L.C. Boggs, John H. Overton, 3, Russell B. Long, Joe D. Waggonner
		Pearl River (PR)	3	1, 2, 3
	MVN (B2)	Old River (OD)	1	Old River
		Atchafalaya River (AT)	1	Berwick
		Gulf Intra-coastal Waterway (GI)	10	Port Allen, Bayou Sorrel, Inner Harbor Navigation Canal, Algiers, Harvey, Bayou Boeuf, Leland Bowman, Calcasieu, Schooner Bayou Control Structure, Catfish Point Control Structure
		Bayou Tech (BT)	1	Keystone
		Freshwater Bayou (FB)	1	Freshwater Bayou
		Calcasieu River (CA)	1	Calcasieu Salt Water Barrier
LRD	LRH (H1)	Kanawha River (KA)	3	Winfield, Marmet, London
		Ohio River (OH)	6	Willow Island, Belleville, Racine, Greenup, Robert C. Byrd , Capt. A. Meldahl,
	LRL (H2)	Green & Barren R. (GB)	4	1, 2
		Ohio R. (OH)	9	Olmsted, 53, 52, Smithland, J.T. Myers, Newburgh, Cannelton, McAlpine, Markland
	LRN (H3)	Clinch River (CI)	1	Melton Hill
		Cumberland River (CU)	4	Barkley, Cheatham, Old Hickory
		Tennessee River (TN)	9	Kentucky, Pickwick, Wilson, Wheeler, Guntersville, Nickajack, Chickamauga, Watts Bar, Ft. Loudon
	LRP (H4)	Allegheny River (AG)	8	2, 3, 4, 5, 6, 7, 8, 9
		Monongahela River (MN)	10	2, 3, 4, Maxwell, Grays Landing, 7, Point Marion, Morgantown, Hidebrand, Opekiska
		Ohio River (OH)	6	Hannibal, Pike Island, New Cumberland, Montgomery, Dashields, Emsworth

Division	District (EROC)	River (Code)	# of Locks	Names of Lock
LRD	LRB (H5)	Black Rock Channel & Tonawanda Harbor (BR)	1	Black Rock
	LRE (H7)	Fox River (FX).	19	De Pere, Litle Kaukauna, Rapide Croche, Kaukauna Guard, Kaukauna 1~5, Little Chute Guard, Little Chute 2, Upper Little Chute Combined, Lower Little Chute Combined, Cedars, Appleton 1~4, Menasha
		St. Marys River (SM)	4	Sabin, Davis, New Poe, MacArthur
		The Inland Route (IN)	1	Alanson
	LRC (H6)	Chicago Harbor Cha.	1	Chicago
SWD	SWL (M4)	McClellan-Kerr Arkansas River Navigation System (MK)	12	Norrell, 2, Joe Hardin, Emmett Sander, 5, David D. Terry, Murray, Toad Suck Ferry, Arthur V. Ormond, Dardanelle, Ozark, James W. Trimble
	SWT (M5)	McClellan-Kerr Arkansas River Navigation System (MK)	5	W.D. Mayo, Robert S. Kerr, Webbers Falls, Chouteau, Newt Graham
	SWG (M3)	Gulf Intra-coastal Waterway (GI)	4	Colorado River East, Colorado River West, Brazos East Gate, Brazos West Gate
SAD	SAM (K5)	Alabama-Coosa River (AL)	3	Claiborne, Millers Ferry, Robert F. Henry
		Black Warrior & Tombigee Rivers (BW)	6	Coffeeville, Demopolis, Selden, William Bacon Oliver, Holt, John Hollis Bankhead
		Tennessee Tombigbee Waterway (TT)	10	Howell Heflin, Tom Bevill, John C. Stennis, Aberdeen, Amory, Glover Wilkins, Fulton, John Rankin, G.V. Sonny Montgomery, Jamie L. Whitten
		Apalachicola, and Chattahoochee Flint Rivers (AP)	3	Jim Woodruff, George W. Andrews, Walter F. George
	SAJ (K3)	Canaveral Harbor (CN)	1	Canaveral
		Cross Florida Barge Canal (CF)	3	Henry Holland Buckman, Eureka, Inglish
		Okeechobee Waterway (OK)	5	St. Lucie, Port Mayaca, Moore Have, Ortona, W.P. Franklin Lock and Control Structure
		Oklawaha River (OL)	1	Moss Bluff
	SAS (K6)	Savannah River (SV)	1	New Savannah Bluff
	SAW (K7)	Cape Fear River (FR)	3	1, 2, William O. Huske
NAD	NAN (E3)	Hudson River (HU)	1	Troy
	NAO (E4)	Atlantic Intra-Coastal Waterway (AI)	1	Great Bride Lock (Albemarle & Chesapeak Canal)
		Dismal Swamp Canal Route (DS)	2	Deep Creek, South Mills
NWD	NWS (G3)	Lake Washington Ship Canal (WS)	1	Hiram M. Chittenden
	NWP (G2)	Willamette River (WI)	2	Willamette Falls 1-4, Willamette Falls Guard
		Columbia River (CO)	3	Bonneville, The Dalles, John Day
	NWW (G4)	Columbia River (CO)	1	McNary
		Snake River (SN)	4	Ice Harbor, Lower Monumental, Little Goose, Lower Granite

2.2. Data

U.S. Army Corps of Engineers OMNI data compiled from 2000 through 2004 are used to conduct this analysis; vessel IDs and types, locations of lockage (i.e., lock, river, and district codes), travel directions, and times of lockages are extracted from the OMNI data.

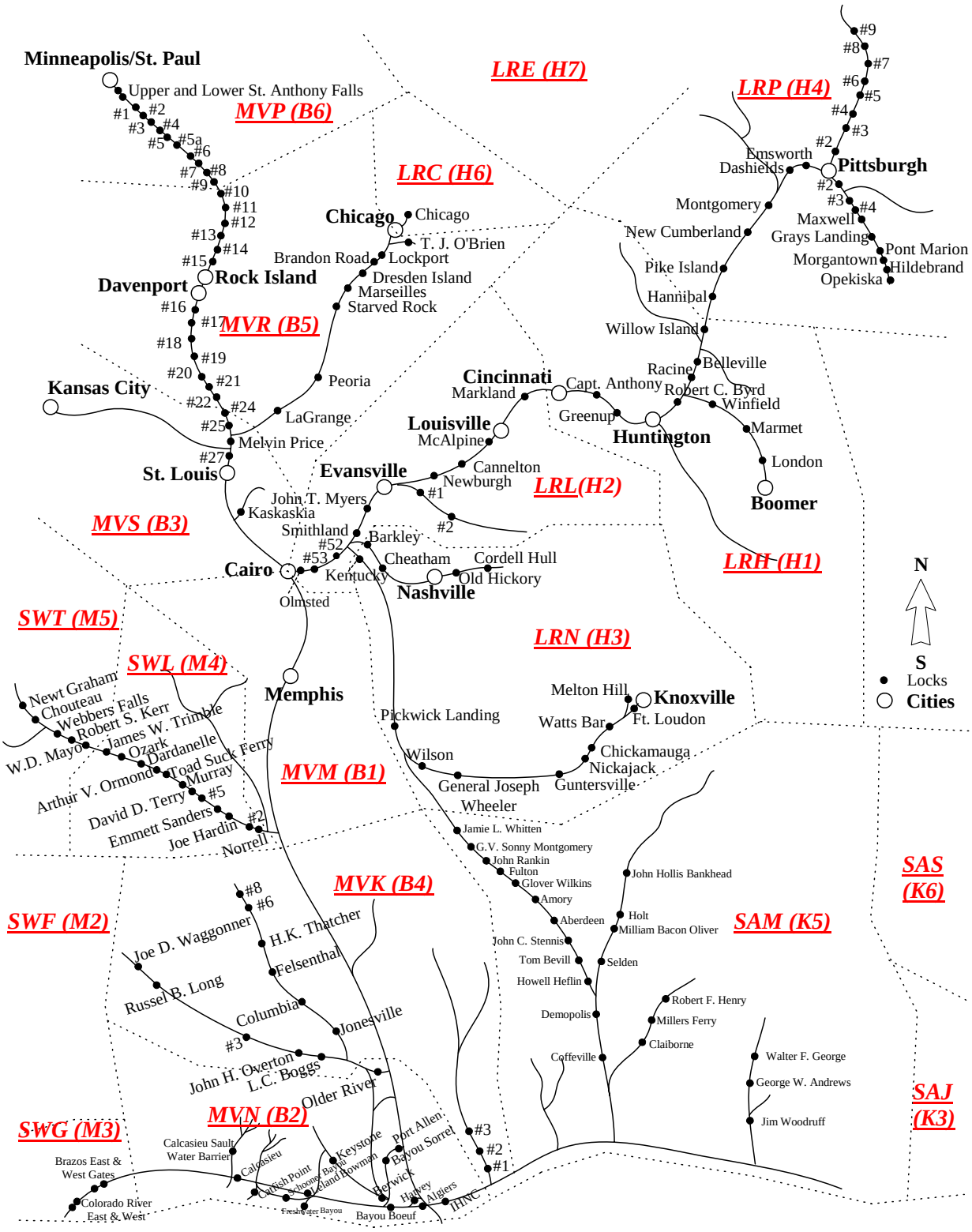


Figure 2. Lock Names in the Study Area[2]

[2] Locks which are shaded in Table 3 are not covered within Figure 2.

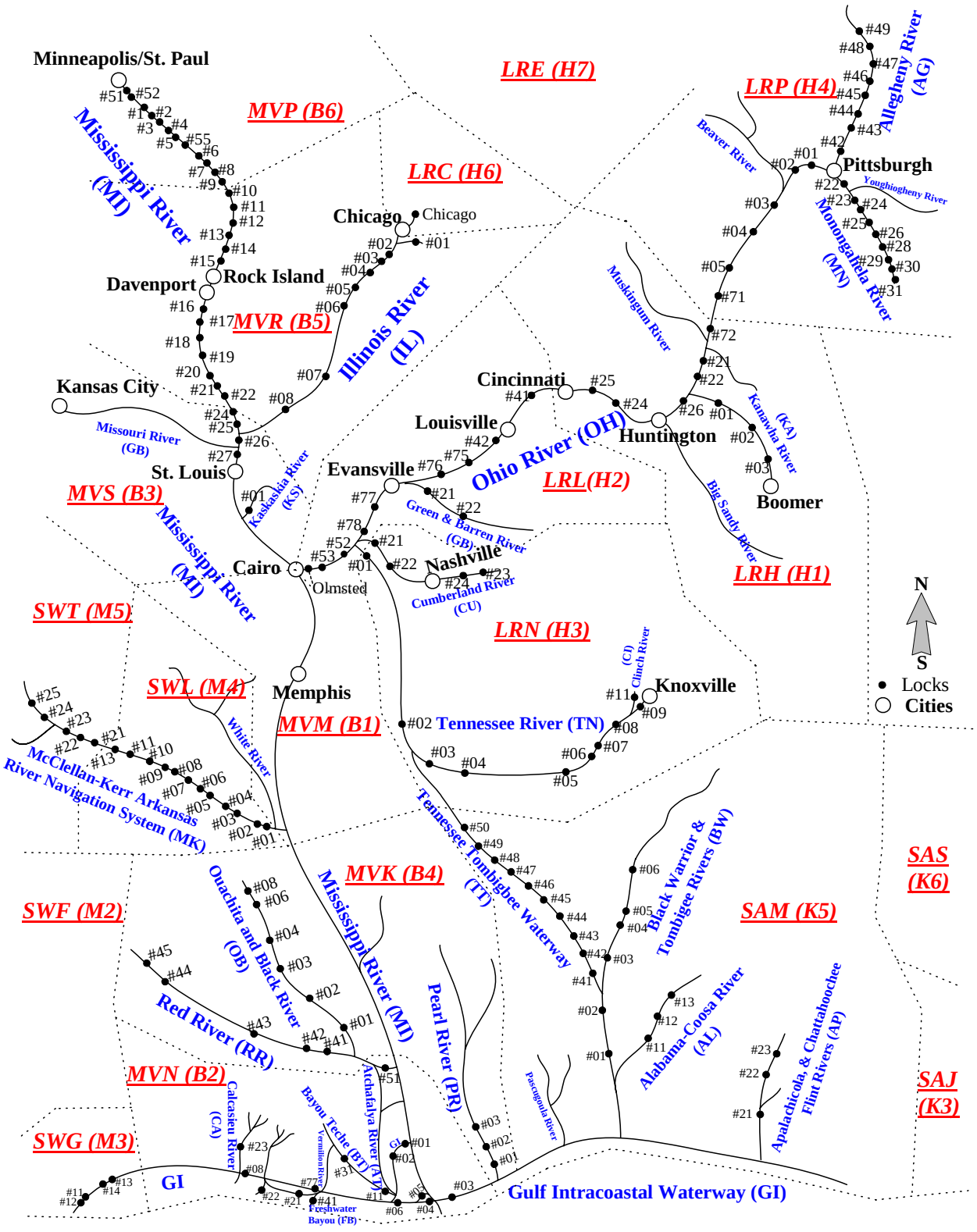


Figure 3. Lock Numbers in the Study Area[3]

[3] Locks which are designated as in Figure 2

2.3. Definition of Towboat Lockages

We try to identify all towboats passing through locks in the study area to track movements of the unique towboats utilizing the UMR locks. However, it is noted that the tracking process may miss some vessels that are operating but are not traveling through locks. In this study, towboat lockages at a lock are defined as lockages by towboats, whether in tow or light, that pass through the lock. For example, if one towboat carrying several barges and three other towboats moving as light boats pass through a certain lock together, the number of towboat lockages for this movement is counted as four. However, counting and identifying towboats at a lock may be difficult since some light boats are locked together with a towboat carrying barges, without being clearly identified. In the current data recording system (such as LPMS and OMNI) some records show that x number of light boats are locked with a specific towboat; however, the information about those light boats is not recorded. The limitations and quality of the data recording system are well summarized in a recent study by Lisney (2005).

2.4. Seasonal Variation of Towboat Lockages

As shown in Figure 4, towboat lockages are steadily distributed over 12 months for most districts in the study area; however, those for the districts in the northern part of the Mississippi Valley Division (MVD) (i.e., Saint Paul (MVP), Rock Island (MVR), and Saint Louis (MVS)) fluctuate. This indicates that monthly towboat lockages in districts in the northern MVD are seasonal; however, those at the other districts are largely uniform. It is noted that the UMR, Illinois, and Ohio are three major rivers which are closely connected in the northern MVD (particularly in the MVS) so that towboats can easily shift among those rivers. Thus, seasonal use of towboats on one of those three rivers may affect the other two.

Towboat operation in the UMR system is not stable; towboats enter the UMR system in the early spring and leave the system in late fall. According to Sweeney (2005) and the CTS at the University of Missouri–St. Louis (2005), towboats that choose to operate on the UMR system during the peak period exit the UMR during the winter because they can earn higher profits elsewhere. Those studies imply that the towboats are always busy; however, some towboats may not operate during the winter due either to freezing of the river or lack of demand. In order to identify the fraction of the towboats that continue to operate during the winter, three distinct UMR time frames are specified based on its monthly towboat traffic over 12 months. Based on the specified periods, we determine the unique towboats which contribute most UMR lockages during the peak period and then try to track them during the off-peak. Additionally, there are no recorded towboat lockages in the Buffalo (LRB), Chicago (LRC), Detroit (LRE), and New York (NAN) districts despite the presence of locks, as shown in Figure 4. This suggests that traffic in those districts is mostly recreational; hence, we disregard those districts in the study area.

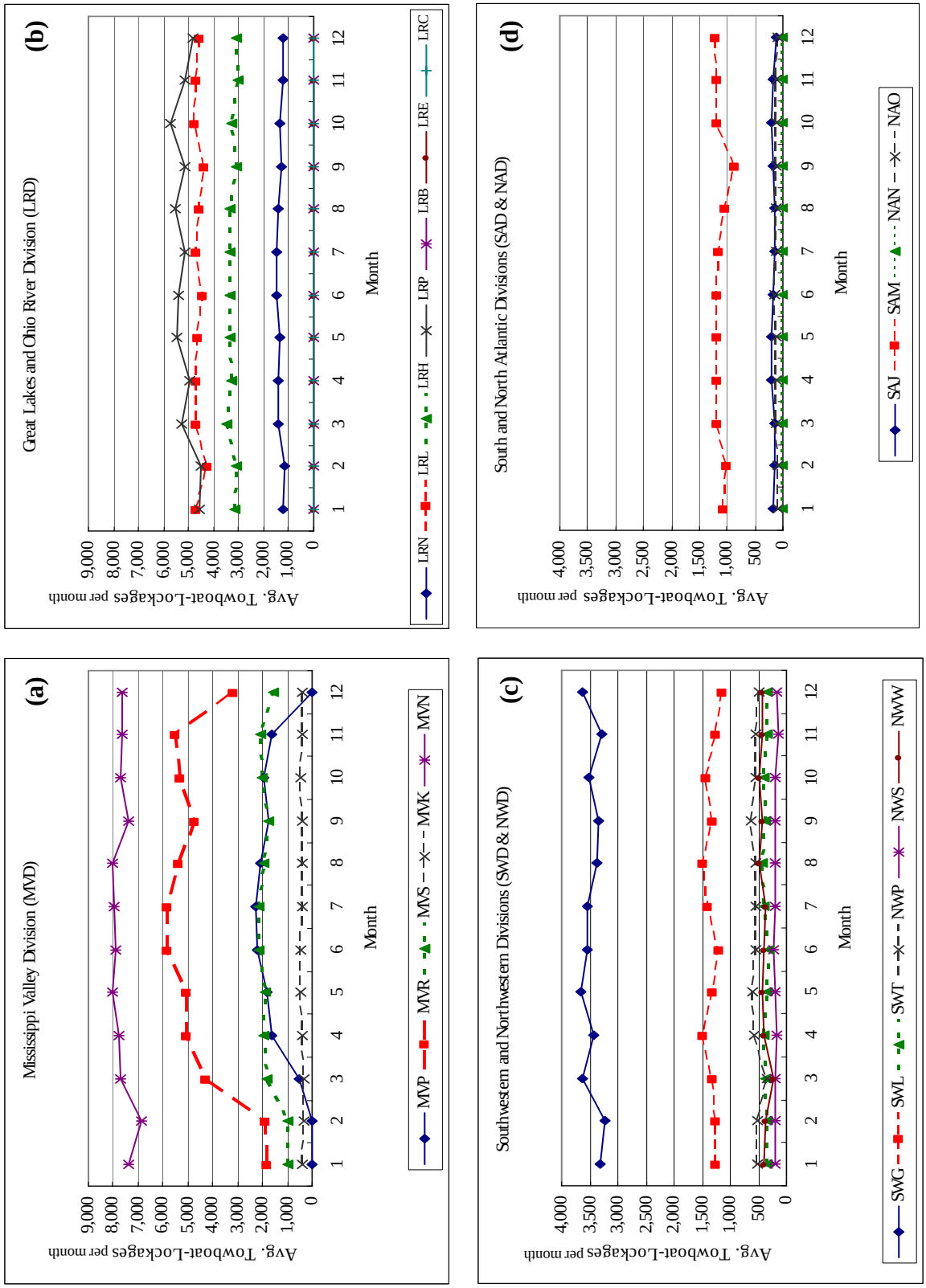


Figure 4. Average Monthly Towboat Lockages by Districts(2000-2004)

Figure 5 presents average monthly towboat lockages over 12 months for the three distinct rivers (the UMR, Illinois, and Ohio) during 2000-2004. As shown in Figure 5, the average monthly towboat lockages in the UMR system fluctuate seasonally while there is no significant seasonal variation in the Ohio and Illinois. In the UMR system, towboats generate steadily many lockages in April through November and steadily few lockages during January and February. Furthermore, distinct transition stages are evident between the peak and off-peak periods. We subdivide the UMR towboat traffic into three different stages (Peak, Off-Peak, and Transition) and summarize them in Table 4. It has been observed that 808 unique towboats operate in the UMR in a year, on average. Among them only 52% (419 towboats) operate during the off-peak while 96% (778 towboats) operate during the peak. This statistic shows that many peak-period towboats on the UMR would cease their operation or move elsewhere during the off-peak of the UMR.

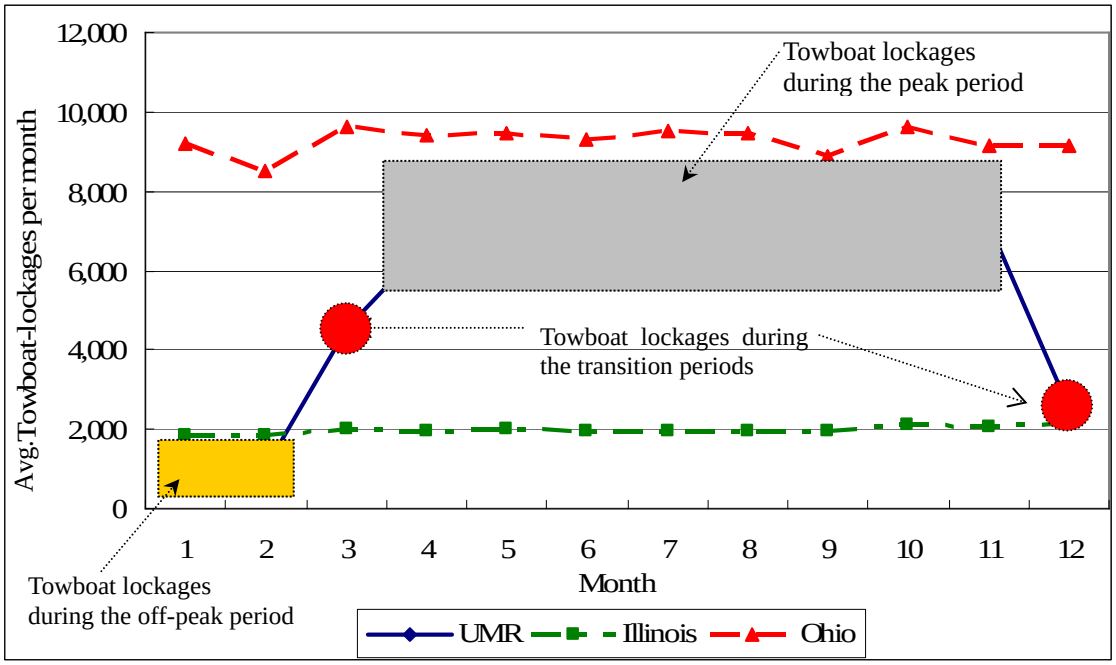


Figure 5. Average Monthly Towboat Lockages for the UMR, Illinois, and Ohio (2000-2004)

Table 4. Three Notable States of UMR Towboat Traffic over 12 Months

	Peak	Transition	Off-Peak	Entire
Period	Apr. through Nov.	Mar. and Dec.	Jan. through Feb.	Jan. through Dec.
Towboat Traffic	High and Steady	Fluctuating	Low and Steady	-
Number of Operating Tows, on Average	778	579	419	808

3. TOWBOAT MOVEMENTS

3.1. Identification of Unique Towboats Using the UMR Locks during the Peak

In section 2.4., we specified three distinct time frames for the UMR system (peak, off-peak, and transition periods). Now we try to determine unique towboats that normally operate in the UMR system during the peak and that contribute most peak-period UMR lockages. In order to identify the unique towboats having such characteristics, we define the unique towboats required to account for 90% of peak-period UMR towboat lockages.

Figure 6 shows cumulatively the average towboat lockages generated by each unique towboat using the UMR locks during the peak period. The busiest towboats (starting with #1) are on the left. It is noted that among the 778 unique towboats using the UMR locks during the peak period (refer to Table 4), the top 203 towboats generate 90% of the peak-period UMR towboat lockages. These towboats are tracked during the off-peak period in the next section, using the observed lockage information from the UMR and other rivers.

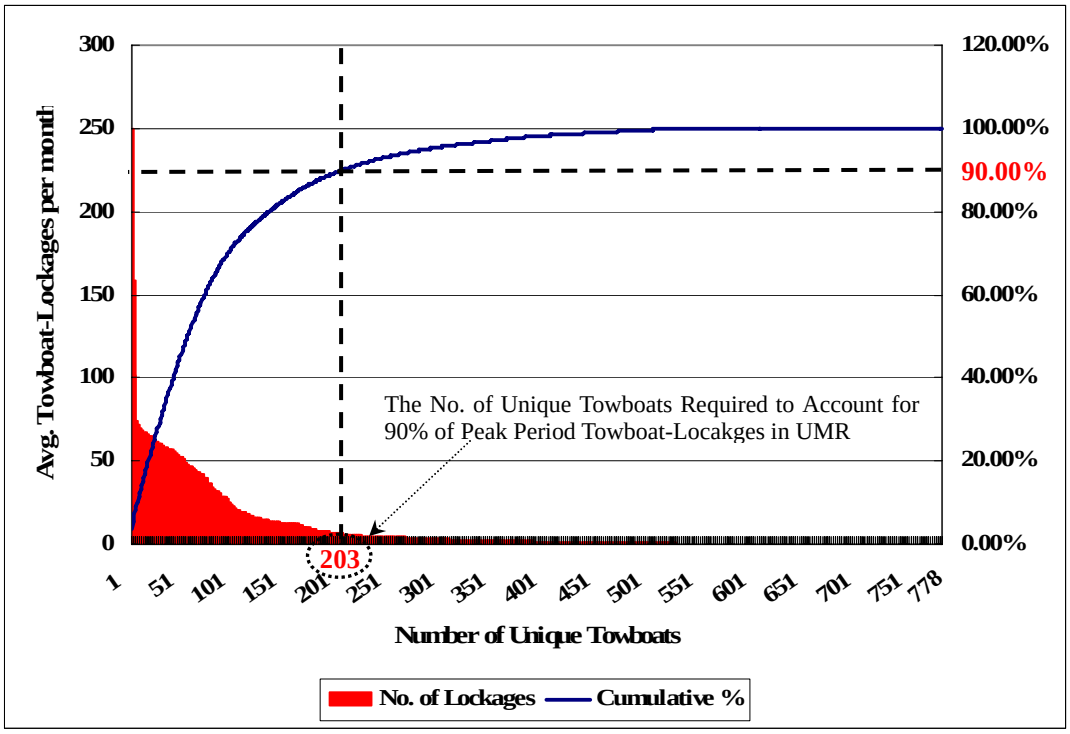


Figure 6. Average Monthly Towboat Lockges Generated by the Unique Towboats Using the UMR Locks during the Peak Period (2000-2004)

3.2. Tracking of Towboats during the UMR Off-peak (Jan. and Feb.)

In this section the unique towboats in the 90% group (203 in total) are tracked individually during the UMR off-peak. The tracked information for each unique towboat, including its observed off-peak lockages (average monthly) in different river systems, is presented in every line of Table 5. It is noted that during the off-peak period, the unique towboats are never observed outside the rivers presented in Table 5. In addition, numbers presented in the leftmost column of Table 5 specify the ranks of the busiest unique towboats during the UMR peak based on their observed lockages (in the second left column in Table 5). The shaded cells in Table 5 indicates whether each unique towboat is observed in corresponding rivers. This shows that the unique towboats are mostly observed in the UMR, Illinois, and Ohio systems during the off-peak and slightly in the Tennessee River (TN), McClellan-Kerr Arkansas River Navigation System (MK), and Gulf Intra-coastal Waterway (GI). More interestingly: (i) the top three unique towboats, which generate considerable UMR lockages during the peak, are not observed at any locks in the study area during the off-peak; furthermore, (ii) UMR lockages by most unique towboats decrease significantly during the off-peak (refer to left second and fourth columns in Table 5). Presumably, these are two of the main reasons why total UMR towboat lockages decrease significantly during the off-peak.

Decrease overall

Table 5. Tracking Results for the 90% Towboats during the UMR Off-Peak (2000-2004)

Rank **4** of the Unique Tows	Average Monthly Towboat Lockages Generated by the 90% Unique Towboats													Unit: Towboat Lockages/month
	During the UMR Peak		**During the UMR Off-peak**											
	In the UMR	Outside the UMR	In the UMR (%of the peak)	Outside the UMR **5**										
				IL	OH	TN	CU	GB	MN	MK	OD	OB	GI	TT	Total
1	250	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
2	158	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
3	102	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
4	74	1	12 (16%)	7	0	0	0	0	0	0	0	0	0	0	7
4	74	1	8 (11%)	17	1	0	0	0	0	0	0	0	0	0	18
6	72	2	11 (15%)	19	0	0	0	0	0	0	0	0	0	0	19
6	72	4	10 (14%)	18	0	0	0	0	0	0	0	0	0	0	18
8	70	0	6 (9%)	11	0	0	0	0	0	0	0	0	0	0	11
8	70	3	12 (17%)	17	0	0	0	0	0	0	0	0	0	0	17
10	68	2	3 (4%)	8	16	0	0	0	0	0	0	0	0	0	24
11	67	1	12 (18%)	6	0	0	0	0	0	0	0	0	0	0	6
11	67	0	6 (9%)	12	2	0	0	0	0	0	0	0	0	0	14
11	67	1	12 (18%)	9	0	0	0	0	0	0	0	0	0	0	9
14	66	2	0 (0%)	0	26	2	0	0	0	0	0	0	0	0	28
14	66	2	3 (5%)	6	13	0	0	0	0	0	0	0	0	0	19
16	65	2	1 (2%)	2	23	0	0	0	0	0	0	0	0	0	25
16	65	3	13 (20%)	18	0	0	0	0	0	0	0	0	0	0	18
16	65	3	2 (3%)	5	25	0	0	0	0	0	0	0	0	0	30
16	65	3	6 (9%)	7	0	0	0	0	0	0	0	0	0	0	7
20	64	0	11 (17%)	0	0	0	0	0	0	0	0	0	0	0	0
21	63	6	15 (22%)	15	7	0	0	0	0	0	0	0	0	0	22
22	62	1	2 (3%)	4	0	0	0	0	0	0	0	0	0	0	4

[4] The busiest unique towboats during the UMR peak (starting with # 1) are on the top.
[5] Refer to Table 3 for river codes. The unique tows are never observed in the other rivers absent from Table 5.

Rank of the Unique Tows	Average Monthly Towboat Lockages Generated by the 90% Unique Towboats																Unit: Towboat Lockages/month
	During the UMR Peak		**During the UMR Off-peak**														
	In the UMR	Outside the UMR	In the UMR (%of the peak)		Outside the UMR												
					IL	OH	TN	CU	GB	MN	MK	OD	OB	GI	TT	Total	
22	62	6	6	(10%)	8	0	0	0	0	0	0	0	0	0	0	8	
22	62	6	1	(2%)	3	26	1	0	0	0	0	0	0	0	0	30	
25	61	5	2	(3%)	3	22	2	0	0	0	0	0	0	0	0	27	
25	61	3	10	(15%)	11	0	0	0	0	0	0	0	0	0	0	11	
27	60	4	2	(3%)	3	27	0	0	0	0	0	0	0	0	0	30	
27	60	3	0	(0%)	0	37	0	0	0	0	0	0	0	0	0	37	
29	59	10	15	(25%)	16	0	0	0	0	0	0	0	0	0	0	16	
29	59	1	2	(3%)	3	0	0	0	0	0	0	0	0	0	0	3	
31	58	3	7	(12%)	13	0	0	0	0	0	0	0	0	0	0	13	
31	58	6	3	(5%)	7	20	0	0	0	0	0	0	0	0	0	27	
31	58	6	0	(0%)	0	20	0	0	0	0	0	0	0	0	0	20	
31	58	4	1	(2%)	3	28	0	0	0	0	0	0	0	0	0	31	
35	57	0	1	(2%)	4	0	0	0	0	0	0	0	0	0	0	4	
35	57	5	11	(19%)	19	0	0	0	0	0	0	0	0	0	0	19	
35	57	7	4	(7%)	5	16	0	0	0	0	0	0	0	0	0	21	
35	57	8	15	(25%)	14	2	0	0	0	0	0	0	0	0	0	16	
35	57	6	3	(5%)	6	16	3	0	0	0	0	0	0	0	0	25	
40	56	10	3	(5%)	3	18	2	0	0	0	0	0	0	0	0	23	
40	56	7	5	(9%)	15	0	0	0	0	0	0	0	0	0	0	15	
42	55	7	1	(2%)	3	30	0	0	0	0	0	0	0	0	0	33	
42	55	5	3	(5%)	5	13	0	0	0	0	0	0	0	0	0	18	
44	54	6	12	(22%)	9	0	0	0	0	0	0	0	0	0	0	9	
45	53	1	1	(2%)	2	1	0	0	0	0	0	0	0	0	0	3	
45	53	11	12	(23%)	15	4	0	0	0	0	0	0	0	0	0	19	
47	52	8	8	(15%)	3	5	0	0	0	0	0	0	0	0	0	8	
47	52	3	5	(10%)	3	0	0	0	0	0	0	0	0	0	0	3	
47	52	6	2	(4%)	5	30	0	0	0	0	0	0	0	0	0	35	
50	51	3	0	(0%)	0	0	0	0	0	0	0	0	0	0	0	0	
51	50	3	4	(8%)	4	0	0	0	0	0	0	0	0	0	0	4	
52	49	8	18	(35%)	14	0	0	0	0	0	0	0	0	0	0	14	
53	48	7	3	(6%)	5	20	1	0	0	0	0	0	0	0	0	26	
53	48	12	6	(13%)	10	0	0	0	0	0	0	0	0	0	0	10	
55	47	12	3	(6%)	4	0	0	0	0	0	0	0	0	0	0	4	
55	47	9	2	(4%)	6	16	0	0	0	0	0	0	0	0	0	22	
55	47	8	5	(11%)	9	5	1	0	0	0	0	0	0	0	0	15	
55	47	11	6	(13%)	6	14	1	0	0	0	0	0	0	0	0	21	
59	46	7	7	(15%)	6	22	0	0	0	0	0	0	0	0	0	28	
59	46	10	1	(2%)	5	0	0	0	0	0	0	0	0	0	0	5	
61	44	11	3	(7%)	11	21	0	0	0	0	0	0	0	0	0	32	
61	44	4	0	(0%)	0	1	0	0	0	0	2	0	0	0	0	3	
63	43	3	14	(30%)	14	0	0	0	0	0	0	0	0	0	0	14	
63	43	12	3	(7%)	2	11	0	0	0	0	0	0	0	0	0	13	
63	43	12	4	(9%)	2	25	0	0	0	0	0	0	0	0	0	27	
66	42	2	2	(5%)	3	3	0	0	0	0	0	0	0	0	0	6	
66	42	15	6	(14%)	13	12	0	0	0	0	0	0	0	0	0	25	
66	42	16	1	(2%)	1	25	0	0	0	0	0	0	0	0	0	26	
69	41	13	5	(12%)	3	8	1	0	0	0	0	0	0	0	0	12	
70	40	3	3	(8%)	1	0	0	0	0	0	0	0	0	0	0	1	
70	40	6	2	(5%)	2	0	0	0	0	0	0	0	0	0	0	2	
70	40	7	9	(23%)	17	5	0	0	0	0	0	0	0	0	0	22	
73	38	12	2	(5%)	7	12	2	0	0	0	0	0	0	0	0	21	
74	37	8	1	(3%)	3	7	0	0	0	0	0	0	0	0	0	10	
75	36	4	2	(6%)	2	8	0	0	0	0	0	0	0	0	0	10	
75	36	5	1	(3%)	0	15	0	0	0	0	0	0	0	0	0	15	
77	34	0	0	(0%)	0	0	0	0	0	0	0	0	0	0	0	0	
78	33	14	14	(39%)	13	0	0	0	0	0	0	0	0	0	0	13	
78	33	5	3	(9%)	2	2	0	0	0	0	0	0	0	0	0	4	
80	32	0	0	(0%)	0	0	0	0	0	0	0	0	0	0	0	0	
80	32	11	1	(3%)	0	17	0	0	0	0	0	0	0	0	0	17	
80	32	0	0	(0%)	0	0	0	0	0	0	0	0	0	0	0	0	
80	32	5	1	(3%)	1	0	0	0	0	0	0	0	0	0	0	1	
84	31	15	5	(16%)	8	9	0	0	0	0	0	0	0	0	0	17	

Rank of the Unique Tows	Average Monthly Towboat Lockages Generated by the 90% Unique Towboats															Unit: Towboat Lockages/month
	During the UMR Peak		**During the UMR Off-peak**													
	In the UMR	Outside the UMR	In the UMR (%of the peak)	Outside the UMR												
				IL	OH	TN	CU	GB	MN	MK	OD	OB	GI	TT	Total
84	31	9	6 (19%)	6	9	0	0	0	0	0	0	0	0	0	15
86	29	4	7 (24%)	11	0	0	0	0	0	0	0	0	0	0	11
86	29	7	3 (10%)	2	5	0	0	0	0	0	0	0	0	0	7
88	28	0	4 (14%)	1	0	0	0	0	0	0	0	0	0	0	1
88	28	20	4 (14%)	7	17	1	0	0	0	0	0	0	0	0	25
88	28	7	0 (0%)	0	14	0	0	0	0	9	0	0	0	0	23
91	27	15	0 (0%)	0	0	0	0	0	0	0	0	0	13	0	13
91	27	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
93	25	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
93	25	0	18 (72%)	0	0	0	0	0	0	0	0	0	0	0	0
93	25	14	2 (8%)	6	23	0	0	0	0	0	0	0	0	0	29
96	24	17	0 (0%)	0	26	0	0	0	0	0	0	0	0	0	26
97	23	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
97	23	24	0 (0%)	0	29	0	0	0	0	0	0	0	0	0	29
99	22	21	1 (5%)	4	16	0	0	0	0	0	0	0	0	0	20
100	21	33	1 (5%)	4	48	0	0	0	0	0	0	0	0	0	52
101	20	9	1 (5%)	1	10	0	0	0	0	0	0	0	2	0	13
101	20	19	6 (30%)	19	0	0	0	0	0	0	0	0	0	0	19
103	20	23	2 (10%)	2	27	0	0	0	0	0	0	0	0	0	29
104	19	8	0 (0%)	0	9	0	0	0	0	4	0	0	0	0	13
104	19	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
104	19	14	2 (11%)	1	6	1	0	0	0	0	0	0	0	0	8
104	19	3	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
104	19	3	2 (11%)	0	4	0	0	0	0	0	0	0	0	0	4
104	19	17	4 (21%)	8	15	1	1	0	0	0	0	0	0	0	25
110	18	10	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
110	18	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
110	18	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
113	17	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
113	17	5	4 (24%)	7	4	0	0	0	0	0	0	0	0	0	11
113	17	9	5 (29%)	5	3	1	0	0	0	1	0	0	0	0	10
113	17	2	5 (29%)	4	0	0	0	0	0	0	0	0	0	0	4
117	16	7	1 (6%)	0	3	0	0	0	0	0	0	0	0	0	3
117	16	1	1 (6%)	1	2	0	0	0	0	0	0	0	0	0	3
117	16	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
117	16	1	0 (0%)	0	4	0	0	0	0	0	0	0	0	0	4
117	16	25	3 (19%)	15	1	2	0	0	0	0	0	0	2	0	20
117	16	5	3 (19%)	4	6	0	0	0	0	0	0	0	0	0	10
117	16	16	3 (19%)	6	0	0	0	0	0	0	0	0	0	0	6
124	15	11	4 (27%)	2	6	3	0	0	0	0	0	0	0	0	11
124	15	8	5 (33%)	3	6	0	0	0	0	0	0	0	0	0	9
124	15	30	4 (27%)	13	11	0	0	0	0	0	0	0	0	0	24
124	15	0	15 (100%)	0	0	0	0	0	0	0	0	0	0	0	0
124	15	5	0 (0%)	0	12	0	0	0	0	2	0	0	0	0	14
124	15	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
124	15	13	1 (7%)	1	15	0	0	0	0	0	1	1	1	0	19
124	15	0	5 (33%)	0	0	0	0	0	0	0	0	0	0	0	0
132	14	10	1 (7%)	3	16	0	0	0	0	0	0	0	0	0	19
132	14	1	0 (0%)	0	3	0	0	0	0	0	0	0	0	0	3
132	14	16	1 (7%)	1	6	0	0	0	0	0	0	0	0	0	7
132	14	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
132	14	25	0 (0%)	0	24	6	2	0	0	0	0	0	0	0	32
132	14	6	3 (21%)	4	2	0	0	0	0	0	0	0	3	0	9
132	14	19	3 (21%)	0	3	3	0	0	0	4	0	0	0	0	10
132	14	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
132	14	15	1 (7%)	0	3	0	0	0	0	0	0	0	0	0	3
132	14	0	16 (114%)	0	0	0	0	0	0	0	0	0	0	0	0
142	13	14	0 (0%)	0	6	0	0	0	0	0	0	0	0	0	6
142	13	24	3 (23%)	12	0	0	0	0	0	0	0	0	0	0	12
142	13	12	0 (0%)	1	3	0	0	0	0	0	0	0	0	0	4
142	13	18	3 (23%)	4	15	0	0	0	0	0	0	0	0	0	19

Rank of the Unique Tows	Average Monthly Towboat Lockages Generated by the 90% Unique Towboats														Unit: Towboat Lockages/month
	During the UMR Peak		**During the UMR Off-peak**												
	In the UMR	Outside the UMR	In the UMR (%of the peak)	Outside the UMR											
				IL	OH	TN	CU	GB	MN	MK	OD	OB	GI	TT	Total
142	13	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
147	12	2	0 (0%)	0	0	0	0	0	0	0	0	0	1	0	1
147	12	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
147	12	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
147	12	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
147	12	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
147	12	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
147	12	4	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
147	12	12	2 (17%)	0	6	0	0	0	0	0	0	0	0	0	6
147	12	19	3 (25%)	1	4	2	0	0	0	1	0	0	0	0	8
147	12	14	0 (0%)	0	9	0	0	0	0	0	0	0	0	0	9
147	12	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
147	12	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
147	12	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
160	11	8	3 (27%)	5	8	0	0	0	0	0	0	0	0	0	13
160	11	16	1 (9%)	1	0	4	0	0	0	0	0	0	10	0	15
160	11	5	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
160	11	1	2 (18%)	3	0	0	0	0	0	0	0	0	0	0	3
160	11	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
165	10	15	3 (30%)	5	6	0	0	0	0	8	0	0	0	0	19
165	10	25	2 (20%)	5	15	4	0	0	1	0	0	0	3	0	28
165	10	23	8 (80%)	20	0	0	0	0	0	0	0	0	0	0	20
165	10	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
165	10	21	0 (0%)	0	2	0	0	0	0	3	0	0	9	0	14
165	10	30	0 (0%)	1	20	6	0	0	2	0	0	0	1	0	30
171	9	27	3 (33%)	0	13	10	0	0	0	1	0	0	1	0	25
171	9	18	0 (0%)	2	5	0	0	0	0	1	2	2	7	0	19
171	9	27	0 (0%)	0	18	8	0	0	1	0	0	0	1	0	28
171	9	4	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
171	9	27	0 (0%)	0	38	0	0	0	0	0	0	0	0	0	38
171	9	3	1 (11%)	0	2	0	0	0	0	0	0	0	0	0	2
171	9	1	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
178	8	25	2 (25%)	1	7	1	0	0	0	0	0	0	5	0	14
178	8	1	1 (13%)	0	4	0	0	0	0	0	0	0	0	0	4
178	8	17	0 (0%)	0	4	0	0	0	0	0	0	0	7	0	11
178	8	15	0 (0%)	0	9	0	0	0	0	0	0	0	5	0	14
178	8	0	2 (25%)	0	0	0	0	0	0	0	0	0	0	0	0
178	8	12	2 (16%)	3	0	0	0	0	0	0	0	0	9	2	14
178	8	15	0 (0%)	0	7	0	0	0	0	5	0	0	0	0	12
178	8	16	0 (0%)	0	2	1	0	0	0	0	0	0	8	6	17
178	8	10	0 (0%)	0	4	0	0	0	0	0	0	0	7	0	11
178	8	24	7 (88%)	12	0	0	0	0	0	1	0	0	0	0	13
178	8	28	0 (0%)	0	35	0	0	0	0	0	0	0	0	0	35
178	8	16	1 (13%)	1	4	0	0	0	0	0	0	0	6	0	11
178	8	37	0 (0%)	0	33	0	0	0	0	0	0	0	0	0	33
191	7	6	13 (186%)	0	3	0	0	2	0	0	0	0	0	0	5
191	7	31	6 (86%)	14	12	0	0	0	0	0	0	0	0	0	26
191	7	1	19 (271%)	0	0	0	0	0	0	0	0	0	0	0	0
191	7	9	2 (29%)	2	3	0	0	0	0	1	0	0	4	0	10
191	7	25	2 (29%)	2	11	4	2	0	0	5	0	0	5	0	29
191	7	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
191	7	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
191	7	8	2 (29%)	0	13	0	0	0	0	2	0	0	0	0	15
191	7	0	0 (0%)	0	0	0	0	0	0	0	0	0	0	0	0
191	7	29	7 (100%)	18	0	0	0	0	0	0	0	0	0	0	18
191	7	38	7 (100%)	14	12	0	0	0	0	0	0	0	0	0	26
191	7	5	1 (14%)	0	3	1	0	0	0	0	0	0	0	0	4
203	7	0	4 (67%)	0	0	0	0	0	0	0	0	0	0	0	0
Total	6,444	1,702	676 (10%)	804	1,410	75	5	2	4	50	3	3	110	8	2,474

Decrease significantly

Increase

In order to identify off-peak (winter) states of the unique towboats inside and outside the UMR system, four types of off-peak lockage levels are specified based on the judgment rules listed below.

- ***Negligible:*** *at most 2 observed off-peak lockages per month on average*
- ***Light:*** *3 to 6 observed off-peak lockages per month on average*
- ***Moderate:*** *7 to 29 observed off-peak lockages per month on average*
- ***Heavy:*** *at least 30 observed off-peak lockages per month on average*

It is noted here that according to Table 5 (left second column), every unique towboat in the 90% group generates at least 7 UMR towboat lockages (monthly average) during the peak period. Based on the minimum peak-period lockages in the UMR system, the off-peak lockages of unique towboats are classified into the above four levels. The unique towboats with less than 7 observed off-peak lockages are classified as having a "light" lockage level in the system. Moreover, the unique towboats with no or very few observed off-peak lockages (at most 2 per month) are categorized as having a "negligible" lockage level while "moderate" and "heavy" levels are assigned to those unique towboats having 7 to 29 and more than 30 off-peak lockages, respectively. Unique towboats off-peak states are summarized in Table 6.

Table 6. Off-peak States of the 90% Unique Towboats

Level Code	Off-Peak Lockage Level at the UMR System	Off-Peak Lockage Level at the Outside the UMR	Fraction of the Unique Towboats % (No.)	
A	Negligible	Negligible	21.2% (43)	58% (117)
		Light	9.4% (19)	
		Moderate	20.7% (42)	
		Heavy	6.4% (13)	
B	Light	Negligible	2.0% (4)	26% (53)
		Light	3.0% (6)	
		Moderate	20.7% (42)	
		Heavy	0.5% (1)	
C	Moderate	Negligible	2.5% (5)	16% (33)
		Light	1.0% (2)	
		Moderate	12.8% (26)	
		Heavy	0% (0)	
D	Heavy	Negligible	0% (0)	0% (0)
		Light	0% (0)	
		Moderate	0% (0)	
		Heavy	0% (0)	
Total			100% (203)	

As shown in Table 6, it has been observed that about 58% of the unique towboats practically do not use the UMR locks during the off-peak. Among them about 37% (43 unique tows) are also not observed at any locks outside the UMR during the off-peak (i.e., about 21% of the unique towboats are never observed anywhere in the study area during the off-peak). It is noted, however, that many unique towboats (about 27% of the unique tows) classified in level A operate actively at locks outside the UMR during the off-peak although their UMR off-peak lockage level is negligible. In addition, Table 6 shows that during the off-peak, about 26% (classified in level B) of the unique towboats reduce their UMR operation; instead, most of them (about 81% of the 26%) operate actively outside the UMR. These results are interpreted to indicate that considerable numbers of the 90% unique towboats cease operation or shift to outside UMR during the off-peak. Finally, it has been observed that only about 16% of the unique towboats operate actively in the UMR system as much as during the off-peak as during the peak and most of them also operate outside the system. No heavily operated unique towboats are observed at locks both inside and outside the UMR during the off-peak (e.g., the top three unique towboats are never observed at any locks in the system during the off-peak).

Figure 7 shows the only districts visited by the 90% towboats during the UMR off-peak. The towboats operate actively in districts in the upper Mississippi Valley Division (MVD) and Great Lakes and Ohio River Division (LRD) during the off-peak and travel slightly to some rivers in New Orleans (MVN), Galveston (SWG), Little Rock (SWL), Tulsa (SWT), Mobile (SAM) districts. It is noted that many unique towboats of the 90% group must often pass through the Mississippi (MI) segment in the Memphis District (MVM), which has no locks.

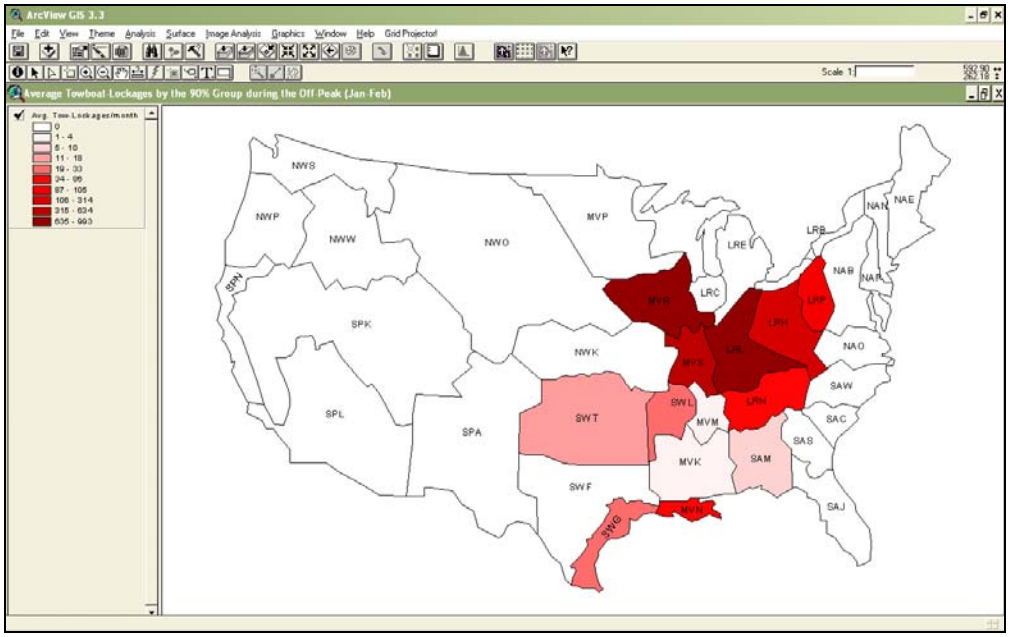


Figure 7. Districts Visited by the 90% Unique Towboats during the UMR Off-peak

3.3. Lock Use by Towboats in the Study Area

In order to identify the impact of the UMR seasonal variation on the other waterways, we determine total towboat lockages as well as the lockages attributable to the 90% unique towboats by locks in the U.S. waterway system. Tables 7 through 10 show the towboat use of locks by rivers. It is noted that there are no observed lockages by the 90% towboats in the North Atlantic Division (NAD) and Northwestern Division (NWD) for 2000-2004; thus, it seems that the UMR seasonality does not affect these areas.

Towboat Lockages in the UMR and Illinois Systems

As shown in the two rightmost columns for the UMR locks in Table 7, there is no significant difference in changes of the UMR towboat lockages generated by all vs. the 90% unique towboats in between the peak and off-peak; both drastically decrease during the off-peak. In particular, the towboat lockages significantly decrease upstream of Lock #25 during the off-peak; however, heavy towboat lockages still observed at Locks #27 and #26 (though the lockages at those locks also decrease significantly during the off-peak). Based on such findings, we conclude that many unique towboats, which normally operate in the UMR during the peak, hardly operate upstream of Lock #25 and would shift to other rivers (e.g., lower Mississippi, Illinois, and Ohio) or cease operating until the UMR thaws (refer to Table 6). Figure 8 presents the UMR lock use by all towboats and the 90% unique towboats for the peak and off-peak periods.

Three key findings are identified from the lock use on the Illinois system, as presented in Table 7 and Figure 9. During the UMR off-peak (i) towboat lockages attributable to the 90% unique towboats increase at every Illinois lock; however, (ii) total towboat lockages at almost every lock in the Illinois decrease overall, except at Lock #01 and the lower Illinois (Locks #07 and #08). In addition, (iii) Lock #01 is hardly used by the 90% unique towboats either in the peak or off-peak of the UMR. Such findings can be interpreted to indicate that among the unique towboats engaging in most peak-period UMR lockages, some towboats shift to the Illinois and operate during the UMR freeze; however, they do not travel to Lock #01[6]. They operate mostly from Lock #08 upstream to Lock #05 during the UMR off-peak and significantly contribute to the increase of off-peak towboat lockages on the lower Illinois (Locks #07 and #08); their contributions to the off-peak towboat lockages at such locks are about 58% and 70%, respectively. However, an interesting question arising here is why do the off-peak towboat lockages at Locks #02 through #06 decrease overall despite an increase there of the off-peak lockages by the 90% unique towboats? A possible answer is that some towboats which normally operate on the Illinois are replaced with towboats shifting from the UMR during

[6] Lock #01 in the Illinois system may be too small or too unimportant (at all times).

winters. We leave this important question to future studies.

Table 7. Lock Use by Towboats in the UMR and Illinois Systems (2000-2004)

unit: Towboat-Lockages/month

River	Lock	During the Peak (Apr. to Nov.)			During the Off-Peak (Jan. to Feb.)			% Change of Towboat-Lockages Between the Peak and Off-Peak	
		towboat-Lockages		% of Total Attributable to the 90% group	towboat-Lockages		% of Total Attributable to the 90% group	% Change of Total	% Change of Tow-Lockages by the 90%
		Total	By the 90% group		Total	By the 90% group			
UMR	MVP(#51)	165	164	99%	0	0	-	-100.00%	-100.00%
	MVP(#52)	160	160	100%	0	0	-	-100.00%	-100.00%
	MVP(#01)	156	146	94%	0	0	-	-100.00%	-100.00%
	MVP(#02)	118	111	94%	0	0	-	-100.00%	-100.00%
	MVP(#03)	129	122	95%	0	0	-	-100.00%	-100.00%
	MVP(#04)	121	115	95%	0	0	-	-100.00%	-100.00%
	MVP(#05)	123	117	95%	0	0	-	-100.00%	-100.00%
	MVP(#55)	130	124	95%	0	0	-	-100.00%	-100.00%
	MVP(#06)	150	143	95%	0	0	-	-100.00%	-100.00%
	MVP(#07)	155	148	95%	0	0	-	-100.00%	-100.00%
	MVP(#08)	150	143	95%	0	0	-	-100.00%	-100.00%
	MVP(#09)	160	153	96%	0	0	-	-100.00%	-100.00%
	MVP(#10)	193	185	96%	0	0	-	-100.00%	-100.00%
	MVR(#11)	222	208	94%	0	0	-	-100.00%	-100.00%
	MVR(#12)	212	201	95%	0	0	-	-100.00%	-100.00%
	MVR(#13)	215	204	95%	0	0	-	-100.00%	-100.00%
	MVR(#14)	293	279	95%	2	1	50%	-99.32%	-99.64%
	MVR(#15)	359	343	96%	3	3	100%	-99.16%	-99.13%
	MVR(#16)	313	300	96%	3	2	67%	-99.04%	-99.33%
	MVR(#17)	276	264	96%	3	2	67%	-98.91%	-99.24%
	MVR(#18)	288	268	93%	3	3	100%	-98.96%	-98.88%
	MVR(#19)	279	260	93%	3	3	100%	-98.92%	-98.85%
	MVR(#20)	295	279	95%	6	6	100%	-97.97%	-97.85%
	MVR(#21)	297	274	92%	10	9	90%	-96.63%	-96.72%
	MVR(#22)	283	266	94%	12	12	100%	-95.76%	-95.49%
	MVS(#24)	293	269	92%	16	16	100%	-94.54%	-94.05%
	MVS(#25)	316	289	91%	18	17	94%	-94.30%	-94.12%
	MVS(#26)	614	442	72%	372	262	70%	-39.41%	-40.72%
	MVS(#27)	710	461	65%	521	340	65%	-26.62%	-26.25%
IL	MVR(#01)	190	2	1%	219	0	0%	15.26%	-100.00%
	MVR(#02)	257	**49**	19%	195	**54**	28%	**-24.12%**	**10.20%**
	MVR(#03)	256	**53**	21%	197	**60**	30%	**-23.05%**	**13.21%**
	MVR(#04)	249	**63**	25%	180	**73**	41%	**-27.71%**	**15.87%**
	MVR(#05)	229	**74**	32%	186	**93**	50%	**-18.78%**	**25.68%**
	MVR(#06)	245	**83**	34%	208	**116**	56%	**-15.10%**	**39.76%**
	MVR(#07)	296	**117**	40%	325	**187**	58%	**9.80%**	**59.83%**
	MVR(#08)	263	**131**	50%	311	**219**	70%	**18.25%**	**67.18%**

Decrease overall

Increase

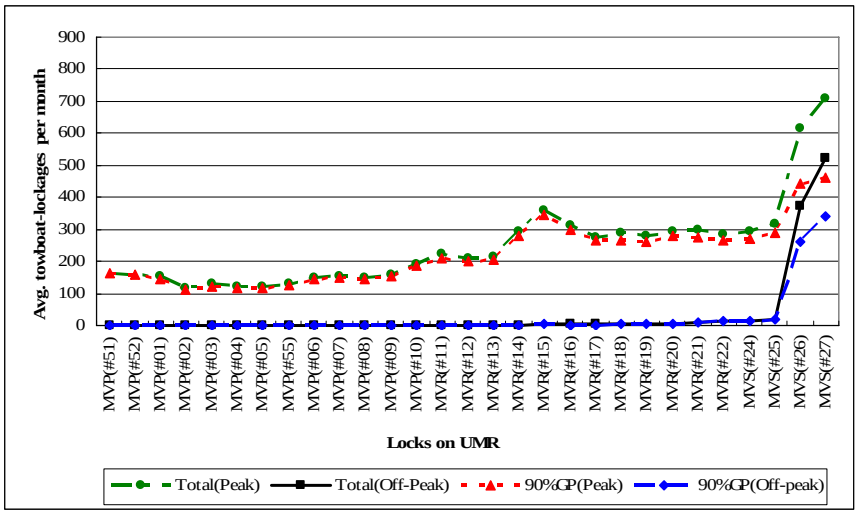


Figure 8. UMR Towboat Lockages during the Peak and Off-peak (2000-2004)

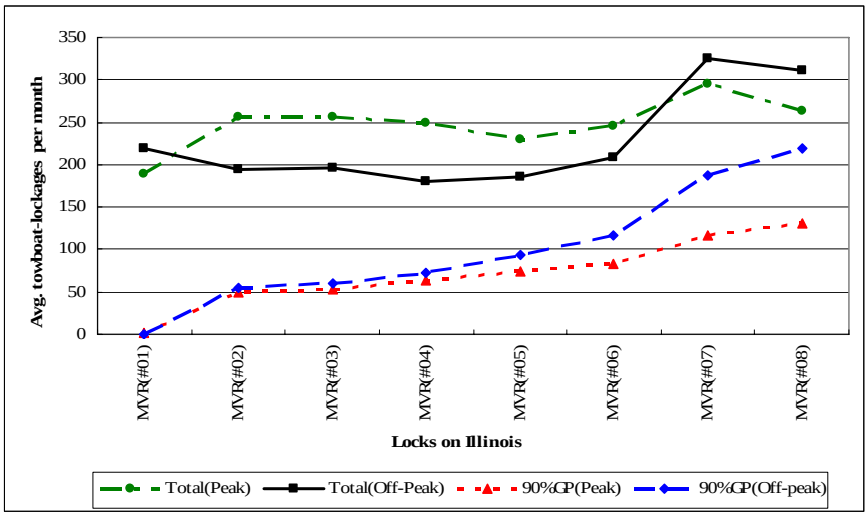


Figure 9. Illinois Towboat Lockages during the UMR Peak and Off-peak (2000-2004)

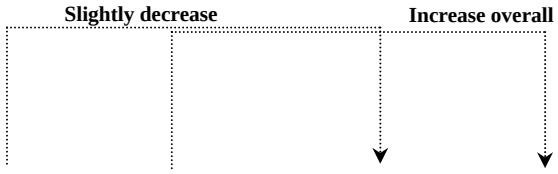
Towboat Lockages in the Ohio and Its Tributaries

During the UMR off-peak, towboat lockages attributable to the 90% unique towboats increase overall at every Ohio lock. This can be interpreted to indicate that among the unique towboats using the UMR locks, some towboats that normally operate on both the UMR and Ohio shift to the Ohio and generate more lockages during the off-peak while avoiding the freezing of the UMR; they operate mostly from Lock #53 upstream to Lock #24 downstream (refer to Table 8 and Figure 10 for the Ohio locks). However, it is clearly noted that total towboat lockages at every Ohio lock are stable in between the UMR peak and off-peak periods although the 90% unique towboats affect more Ohio lockages during the off-peak. This raises some important questions such as: (i) why are the total towboat lockages at every Ohio lock stable despite increase of the towboat lockages by the 90% unique towboats during the off-peak period? (ii) Do some towboats that normally operate on the Ohio cease operation so that they are replaced by the shifted towboats from the UMR during the off-peak? We leave such questions to future studies.

As shown in Figure 11, total towboat lockages at every Tennessee (TN) lock are also stable regardless of season and the contribution of the 90% unique towboats to the total lockages of the systems is insignificant and stable during both the UMR peak and off-peak periods. This indicates that the impact of the unique towboats, which operate in between the UMR and Tennessee systems, to the Tennessee is generally steady and low in spite of the seasonality in the UMR. For other Ohio tributaries, the 90% unique towboats hardly travel to there during both the UMR peak and off-peak periods; furthermore, total towboat lockages on most rivers slightly decrease during the UMR off-peak (see Table 8). Additionally, it should be noted that total

towboat lockages on the upper Allegheny (AG) (upstream of Lock #44) significantly decrease during the winter. It seems traffic on the upper Allegheny is also seasonal as in the UMR case since this river also freezes in winter.

Table 8. Lock Use by Towboats in the Ohio and Its Tributaries (2000-2004)



unit: Towboat-Lockages/month

River	Lock	During the Peak (Apr. to Nov.)			During the Off-Peak (Jan. to Feb.)			% Change of Towboat-Lockages Between the Peak and Off-Peak	
		towboat-Lockages		% of Total Attributable to the 90% group	towboat-Lockages		% of Total Attributable to the 90% group	% Change of Total	% Change of Tow-Lockages by the 90%
		Total	By the 90% group		Total	By the 90% group			
OH	LRL(#53)	**610**	**108**	18%	**595**	**146**	25%	-2.46%	35.19%
	LRL(#52)	**844**	**109**	13%	**791**	**147**	19%	-6.28%	34.86%
	LRL(#78)	**607**	**78**	13%	**615**	**136**	22%	1.32%	74.36%
	LRL(#77)	**491**	**74**	15%	**503**	**131**	26%	2.44%	77.03%
	LRL(#76)	**520**	**70**	13%	**494**	**124**	25%	-5.00%	77.14%
	LRL(#75)	**414**	**62**	15%	**381**	**110**	29%	-7.97%	77.42%
	LRL(#42)	**438**	**61**	14%	**426**	**106**	25%	-2.74%	73.77%
	LRL(#41)	**404**	**52**	13%	**386**	**92**	24%	-4.46%	76.92%
	LRH(#25)	**439**	**46**	10%	**422**	**80**	19%	-3.87%	73.91%
	LRH(#24)	**549**	**44**	8%	**540**	**80**	15%	-1.64%	81.82%
	LRH(#26)	**434**	**28**	6%	**404**	**48**	12%	-6.91%	71.43%
	LRH(#22)	**379**	**24**	6%	**344**	**38**	11%	-9.23%	58.33%
	LRH(#21)	**358**	**22**	6%	**329**	**35**	11%	-8.10%	59.09%
	LRH(#72)	**351**	**20**	6%	**336**	**32**	10%	-4.27%	60.00%
	LRP(#71)	**383**	**20**	5%	**365**	**31**	8%	-4.70%	55.00%
	LRP(#05)	**423**	**17**	4%	**407**	**29**	7%	-3.78%	70.59%
	LRP(#04)	**377**	**15**	4%	**363**	**26**	7%	-3.71%	73.33%
	LRP(#03)	**423**	**5**	1%	**389**	**8**	2%	-8.04%	60.00%
	LRP(#02)	**430**	**2**	0%	**365**	**4**	1%	-15.12%	100.00%
	LRP(#01)	**470**	**2**	0%	**394**	**4**	1%	-16.17%	100.00%
TN	LRN(#01)	274	25	9%	265	20	8%	-3.28%	-20.00%
	LRN(#02)	212	28	13%	190	18	9%	-10.38%	-35.71%
	LRN(#03)	159	13	8%	154	10	6%	-3.14%	-23.08%
	LRN(#04)	145	12	8%	136	10	7%	-6.21%	-16.67%
	LRN(#05)	94	12	13%	80	8	10%	-14.89%	-33.33%
	LRN(#06)	71	8	11%	57	6	11%	-19.72%	-25.00%
	LRN(#07)	56	6	11%	36	2	6%	-35.71%	-66.67%
	LRN(#08)	41	6	15%	27	2	7%	-34.15%	-66.67%
	LRN(#09)	23	6	26%	16	2	13%	-30.43%	-66.67%
CI	LRN(#11)	0	0	-	0	0	-	-	-
CU	LRN(#21)	109	5	5%	68	3	4%	-37.61%	-40.00%
	LRN(#22)	120	6	5%	92	2	2%	-23.33%	-66.67%
	LRN(#24)	69	0	0%	66	0	0%	-4.35%	-
	LRN(#23)	0	0	-	0	0	-	-	-
GB	LRL(#21)	170	4	2%	172	2	1%	1.18%	-50.00%
	LRL(#22)	101	0	0%	110	0	0%	8.91%	-
KA	LRH(#01)	245	0	0%	226	0	0%	-7.76%	-
	LRH(#02)	372	0	0%	354	0	0%	-4.84%	-
	LRH(#03)	139	0	0%	156	0	0%	12.23%	-
MN	LRP(#22)	404	2	0%	357	2	1%	-11.63%	0.00%
	LRP(#23)	655	6	1%	580	2	0%	-11.45%	-66.67%
	LRP(#24)	466	0	0%	392	0	0%	-15.88%	-
	LRP(#25)	350	0	0%	316	0	0%	-9.71%	-
	LRP(#26)	158	0	0%	140	0	0%	-11.39%	-
	LRP(#28)	152	0	0%	132	0	0%	-13.16%	-
	LRP(#29)	45	0	0%	13	0	0%	-71.11%	-
	LRP(#30)	10	0	0%	10	0	0%	0.00%	-
	LRP(#31)	10	0	0%	12	0	0%	20.00%	-
AG	LRP(#42)	126	0	0%	114	0	0%	-9.52%	-
	LRP(#43)	121	0	0%	107	0	0%	-11.57%	-
	LRP(#44)	127	0	0%	43	0	0%	-66.14%	-
	LRP(#45)	90	0	0%	18	0	0%	-80.00%	-
	LRP(#46)	18	0	0%	8	0	0%	-55.56%	-
	LRP(#47)	17	0	0%	6	0	0%	-64.71%	-
	LRP(#48)	84	0	0%	0	0	-	-100.00%	-
	LRP(#49)	0	0	-	0	0	-	-	-

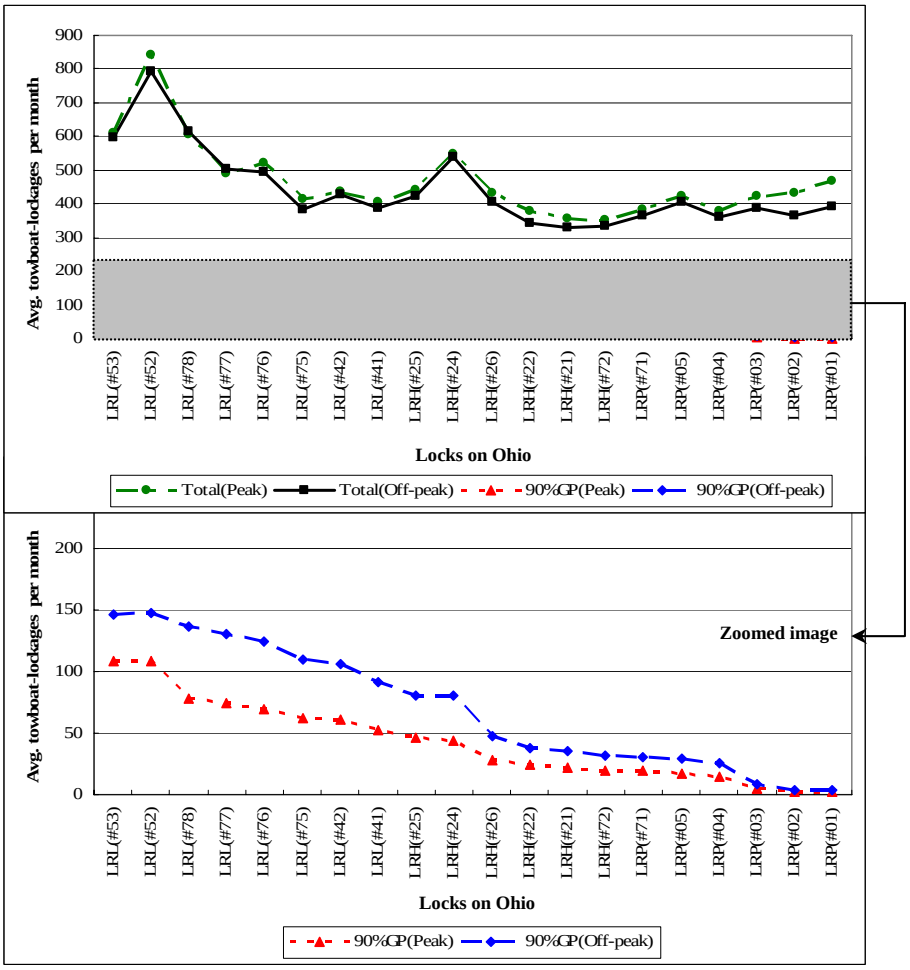


Figure 10. Ohio Towboat Lockages during the UMR Peak and Off-peak (2000-2004)

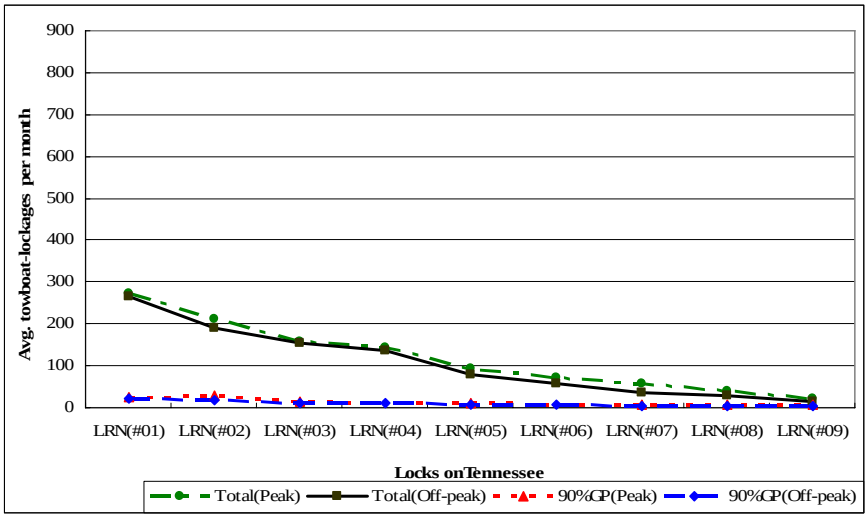


Figure 11. Tennessee Towboat Lockages during the UMR Peak and Off-peak (2000-2004)

Towboat Lockages on the Lower MVD and Southwester Division (SWD)

As shown in Figure 12 and Table 9, total towboat lockages at every Gulf Intra-coastal Waterway (GI) lock decrease overall during the UMR off-peak, except at Lock #01, and the fraction of the total lockages attributable to the 90% unique towboats is negligible (below 2%) during both the UMR peak and off-peak periods. These results indicate that towboats using the Gulf Intra-coastal Waterway reduce their operation during the winter; furthermore, among them some towboats which normally operate in between the UMR and Gulf Intra-coastal Waterway slightly affect Gulf Intra-coastal Waterway lockages with almost stable but insignificant rates during both the UMR peak and off-peak periods. Thus, it seems that the UMR seasonality hardly affects the Gulf Intra-coastal Waterway system. The same interpretation given for the Gulf Intra-coastal Waterway is also applicable to the McClellan-Kerr Arkansas River Navigation System (MK) since total towboat lockages of the McClellan-Kerr Arkansas River Navigation System also slightly decrease during the off-peak and lockages generated by the 90% unique towboats are low and fairly stable (less than 5 lockages per month on average) during both the peak and off-peak periods. Finally, the 90% unique towboats are never observed on the Red River (RR), Pearl River (PR), Atchafalaya River (AT), Bayou Tech (BT), Freshwater Bayou (FB), and Calcasieu River (CA).

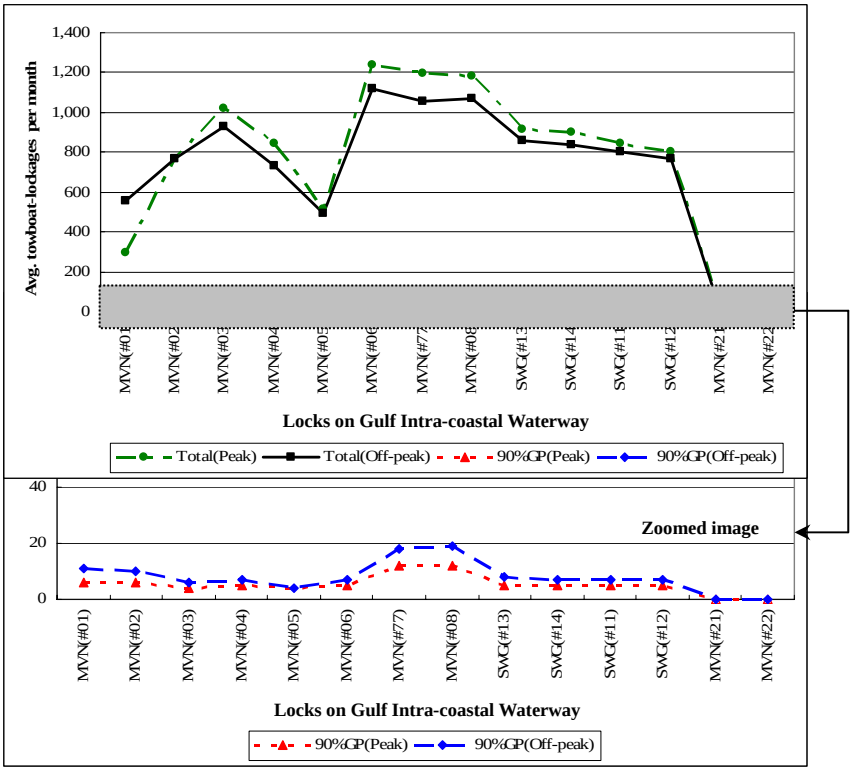


Figure 12. Towboat Lockages on Gulf Intra-coastal Waterway during the UMR Peak and Off-peak (2000-2004)

Table 9. Lock Use by Towboats in the Lower MVD and SWD (2000-2004)

unit: Towboat-Lockages/month

River	Lock	During the Peak (Apr. to Nov.)			During the Off-Peak (Jan. to Feb.)			% Change of Towboat-Lockages Between the Peak and Off-Peak	
		towboat-Lockages		% of Total Attributable to the 90% group	towboat-Lockages		% of Total Attributable to the 90% group	% Change of Total	% Change of Tow-Lockages by the 90%
		Total	By the 90% group		Total	By the 90% group			
GI	MVN(#01)	292	6	2.05%	558	11	1.97%	91.10%	83.33%
	MVN(#02)	767	6	0.78%	764	10	1.31%	-0.39%	66.67%
	MVN(#03)	1,021	4	0.39%	930	6	0.65%	-8.91%	50.00%
	MVN(#04)	842	5	0.59%	729	7	0.96%	-13.42%	40.00%
	MVN(#05)	511	4	0.78%	492	4	0.81%	-3.72%	0.00%
	MVN(#06)	1,236	5	0.40%	1,116	7	0.63%	-9.71%	40.00%
	MVN(#77)	1,196	12	1.00%	1,054	18	1.71%	-11.87%	50.00%
	MVN(#08)	1,180	12	1.02%	1,070	19	1.78%	-9.32%	58.33%
	SWG(#13)	915	5	0.55%	859	8	0.93%	-6.12%	60.00%
	SWG(#14)	901	5	0.55%	834	7	0.84%	-7.44%	40.00%
	SWG(#11)	844	5	0.59%	799	7	0.88%	-5.33%	40.00%
	SWG(#12)	804	5	0.62%	766	7	0.91%	-4.73%	40.00%
	MVN(#21)	6	0	0.00%	9	0	0.00%	50.00%	-
	MVN(#22)	39	0	0.00%	40	0	0.00%	2.56%	-
MK	SWL(#01)	90	3	3.33%	91	5	5.49%	1.11%	66.67%
	SWL(#02)	90	4	4.44%	89	5	5.62%	-1.11%	25.00%
	SWL(#03)	78	3	3.85%	74	5	6.76%	-5.13%	66.67%
	SWL(#04)	79	3	3.80%	76	4	5.26%	-3.80%	33.33%
	SWL(#05)	73	3	4.11%	66	3	4.55%	-9.59%	0.00%
	SWL(#06)	73	3	4.11%	64	2	3.13%	-12.33%	-33.33%
	SWL(#07)	64	2	3.13%	57	2	3.51%	-10.94%	0.00%
	SWL(#08)	64	2	3.13%	60	2	3.33%	-6.25%	0.00%
	SWL(#09)	61	2	3.28%	55	2	3.64%	-9.84%	0.00%
	SWL(#10)	64	2	3.13%	57	2	3.51%	-10.94%	0.00%
	SWL(#11)	38	2	5.26%	36	1	2.78%	-5.26%	-50.00%
	SWL(#13)	42	2	4.76%	34	1	2.94%	-19.05%	-50.00%
	SWT(#21)	78	5	6.41%	74	4	5.41%	-5.13%	-20.00%
	SWT(#22)	80	4	5.00%	73	4	5.48%	-8.75%	0.00%
	SWT(#23)	75	4	5.33%	71	4	5.63%	-5.33%	0.00%
	SWT(#24)	70	3	4.29%	68	3	4.41%	-2.86%	0.00%
	SWT(#25)	69	3	4.35%	65	3	4.62%	-5.80%	0.00%
OD	MVN(#51)	578	2	0.35%	233	3	1.29%	-59.69%	50.00%
OB	MVK(#01)	93	0	0.00%	66	2	3.03%	-29.03%	100.00%
	MVK(#02)	69	0	0.00%	53	1	1.89%	-23.19%	100.00%
	MVK(#03)	16	0	0.00%	14	0	0.00%	-12.50%	-
	MVK(#04)	16	0	0.00%	14	0	0.00%	-12.50%	-
	MVK(#06)	0	0	-	0	0	-	-	-
	MVK(#08)	0	0	-	0	0	-	-	-
RR	MVK(#41)	74	0	0.00%	72	0	0.00%	-2.70%	-
	MVK(#42)	71	0	0.00%	71	0	0.00%	0.00%	-
	MVK(#43)	38	0	0.00%	35	0	0.00%	-7.89%	-
	MVK(#44)	25	0	0.00%	22	0	0.00%	-12.00%	-
	MVK(#45)	16	0	0.00%	11	0	0.00%	-31.25%	-
AT	MVN(#11)	55	0	0.00%	48	0	0.00%	-12.73%	-
BT	MVN(#31)	0	0	-	0	0	-	-	-
FB	MVN(#41)	42	0	0.00%	38	0	0.00%	-9.52%	-
CA	MVN(#23)	40	0	0.00%	29	0	0.00%	-27.50%	-
PR	MVK(#31)	0	0	-	0	0	-	-	-
	MVK(#32)	0	0	-	0	0	-	-	-
	MVK(#33)	0	0	-	0	0	-	-	-

Towboat Lockages in the SAD, NAD, and NWD

Table 10 presents the lock use by towboats on rivers in the South Atlantic Division (SAD), North Atlantic Division (NAD), and Northwestern Division (NWD). As stated previously, the 90% unique towboats are never observed on such rivers during either the UMR peak or off-peak periods, except on the Tennessee Tombigbee Waterway (TT).

Table 10. Lock Use by Towboats in the SAD, NAD, and NWD (2000-2004)

unit: Towboat-Lockages/month

		During the Peak (Apr. to Nov.)			During the Off-Peak (Jan. to Feb.)			% Change of Towboat-Lockages Between the Peak and Off-Peak	
River	Lock	towboat-Lockages		% of Total Attributable to the 90% group	towboat-Lockages		% of Total Attributable to the 90% group	% Change of Total	% Change of Tow-Lockages by the 90%
		Total	By the 90% group		Total	By the 90% group			
BW	SAM(#01)	0	0	-	0	0	-	-	-
	SAM(#02)	223	2	0.90%	217	0	0.00%	-2.69%	-100.00%
	SAM(#03)	0	0	-	0	0	-	-	-
	SAM(#04)	0	0	-	0	0	-	-	-
	SAM(#05)	108	0	0.00%	105	0	0.00%	-2.78%	-
	SAM(#06)	0	0	-	0	0	-	-	-
TT	SAM(#41)	132	1	0.76%	131	1	0.76%	-0.76%	0.00%
	SAM(#42)	80	0	0.00%	68	1	1.47%	-15.00%	-
	SAM(#43)	75	0	0.00%	65	1	1.54%	-13.33%	-
	SAM(#44)	66	0	0.00%	56	1	1.79%	-15.15%	-
	SAM(#45)	66	0	0.00%	56	1	1.79%	-15.15%	-
	SAM(#46)	66	0	0.00%	56	1	1.79%	-15.15%	-
	SAM(#47)	64	0	0.00%	56	1	1.79%	-12.50%	-
	SAM(#48)	64	0	0.00%	55	0	0.00%	-14.06%	-
	SAM(#49)	63	1	1.59%	54	0	0.00%	-14.29%	-100.00%
	SAM(#50)	99	1	1.01%	99	1	1.01%	0.00%	0.00%
AL	SAM(#11)	4	0	0.00%	4	0	0.00%	0.00%	-
	SAM(#12)	0	0	-	0	0	-	-	-
	SAM(#13)	0	0	-	0	0	-	-	-
AP	SAM(#21)	13	0	0.00%	17	0	0.00%	30.77%	-
	SAM(#22)	0	0	-	0	0	-	-	-
	SAM(#23)	1	0	0.00%	0	0	-	-100.00%	-
CN	SAJ(#21)	103	0	0.00%	67	0	0.00%	-34.95%	-
CF	SAJ(#11)	0	0	-	0	0	-	-	-
	SAJ(#12)	0	0	-	0	0	-	-	-
	SAJ(#13)	0	0	-	0	0	-	-	-
OK	SAJ(#01)	29	0	0.00%	36	0	0.00%	24.14%	-
	SAJ(#05)	11	0	0.00%	9	0	0.00%	-18.18%	-
	SAJ(#02)	12	0	0.00%	11	0	0.00%	-8.33%	-
	SAJ(#03)	12	0	0.00%	11	0	0.00%	-8.33%	-
	SAJ(#04)	12	0	0.00%	12	0	0.00%	0.00%	-
OL	SAJ(#31)	0	0	-	0	0	-	-	-
SV	SAS(#01)	0	0	-	0	0	-	-	-
FR	SAW(#01)	0	0	-	0	0	-	-	-
	SAW(#02)	0	0	-	0	0	-	-	-
	SAW(#03)	0	0	-	0	0	-	-	-
HU	NAN(#01)	7	0	0.00%	0	0	-	-100.00%	-
AI	NAO(#11)	116	0	0.00%	98	0	0.00%	-15.52%	-
DS	NAO(#01)	0	0	-	0	0	-	-	-
	NAO(#02)	0	0	-	0	0	-	-	-
WS	NWS(#01)	198	0	0.00%	192	0	0.00%	-3.03%	-
WI	NWS(#11)	2	0	0.00%	1	0	0.00%	-50.00%	-
	NWS(#15)	2	0	0.00%	2	0	0.00%	0.00%	-
CO	NWS(#01)	213	0	0.00%	188	0	0.00%	-11.74%	-
	NWS(#02)	195	0	0.00%	167	0	0.00%	-14.36%	-
	NWS(#03)	167	0	0.00%	152	0	0.00%	-8.98%	-
	NWS(#24)	143	0	0.00%	129	0	0.00%	-9.79%	-
SN	NWS(#01)	95	0	0.00%	88	0	0.00%	-7.37%	-
	NWS(#02)	70	0	0.00%	68	0	0.00%	-2.86%	-
	NWS(#03)	67	0	0.00%	62	0	0.00%	-7.46%	-
	NWS(#04)	50	0	0.00%	48	0	0.00%	-4.00%	-

4. CONCLUSIONS

Throughout this analysis, it is shown that seasonality is prevalent and important in the UMR and affects some other rivers in the U.S. inland waterway system. The UMR traffic is unsteady due to freezing in winter as well as some seasonality in demand for transporting commodities. This study aims to identify the impact of the UMR seasonality on towboat use and shifts to other waterways. To accomplish this we perform several tasks, ultimately tracking the unique towboats that account for most peak- period towboat lockages in the UMR system, during the freezing of the UMR. It should be noted that the results presented in this report rely completely on the observed lockage information at all locks in the study area. The use of Waterborne Commerce Statistics Center (WCSC) data[7], which are not limited to observations at locks, should be considered in future studies.

Key findings from the analysis are summarized below.

1. *The UMR seasonality is significant and driven by freezing during winter as well as seasonal variation in demand.*
    - A. *The UMR has numerous and stable towboat lockages during Apr. through Nov.*
    - B. *The UMR has few and stable towboat lockages during Jan. through Feb.*
    - C. *The towboat lockages of the UMR fluctuate in Dec. and Mar.*
    - D. *Towboats hardly operate upstream of UMR Lock #25 during the off-peak.*
    - E. *Towboat lockages at UMR Locks #27 and #26 significantly decrease during the off-peak (% change of towboat lockages on these locks between the peak and off-peak is 30%, on average; refer to Table 7).*
    - F. *The top three unique towboats, which serve a considerable fraction of the peak period UMR towboat lockages of the UMR, are never observed anywhere in the study area during the off-peak.*
    - G. *It is observed that in the winter (off-peak), about 58% of the unique towboats in the 90% group have practically no use of the UMR locks; moreover, about 21% of the unique towboats are not observed at any locks in the study area. (Refer to Table 6.)*
    - H. *It is observed that in winter, about 27% of the unique towboats operate actively outside the UMR and are practically absent from the UMR locks. (Refer to Table 6.)*
    - I. *It is observed that in winter, about 26% of the unique towboats reduce their UMR*

[7] WCSC data are submitted to the U.S. Army Corps of Engineers by towboat operators, barge operators, and through cargo manifests and custom clearing for foreign data. They contain information about the amount and types of equipment using the waterway system, how the equipment moves around the system, and the types and amount of commodities moved by the equipment *(4)*.

operation; instead, most of them (about 81% of the 26%) operate actively outside the UMR. (Refer to Table 6.)

J. *It is observed that in winter, only about 16% of the UMR unique towboats operate actively as much during the off-peak as during the peak in the study area. (Refer to Table 6.)*

K. *No heavily operated unique towboats are observed inside and outside the UMR during the winter. (Refer to Table 6.)*

2. *The unique towboats which serve most peak-period towboat lockages of the UMR system operate largely in between the UMR, Illinois, and Ohio systems during the UMR off-peak.*
3. *Total towboat lockages on the Illinois decrease overall during the UMR off-peak (the Illinois also freezes farther north); however, they increase on the lower Illinois (Locks #07 and #08) due to towboats shifting from the UMR to avoid its freeze. Therefore, steady state demands are not realistic in modeling the Illinois.*
4. *Total towboat lockages on the Ohio slightly decrease (the reduction is insignificant) during the UMR off-peak although some towboats shifted from the UMR have more lockages while avoiding the UMR freeze. This leads to some questions stated in section 3.3; however, steady state demands on the Ohio system seem acceptable in modeling that system.*
5. *Total towboat lockages on the Gulf Intra-coastal Waterway decrease during the off-peak of the UMR but it seems that the UMR's seasonality hardly affects the use of the GI locks.*
6. *Total towboat lockages on the Tennessee and McClellan-Kerr decrease slightly (the reduction is slight for both rivers) during the off-peak of the UMR and towboat lockages generated by the shifted towboats from the UMR are few and fairly stable all year round.*
7. *No significant seasonal impact of the UMR is observed outside of the UMR, Illinois, and Ohio systems.*

Figures 13 through 15 exhibit average monthly towboat lockages by the 90% unique towboats at every lock in the study area during the peak and off-peak of the UMR.

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APPENDIX

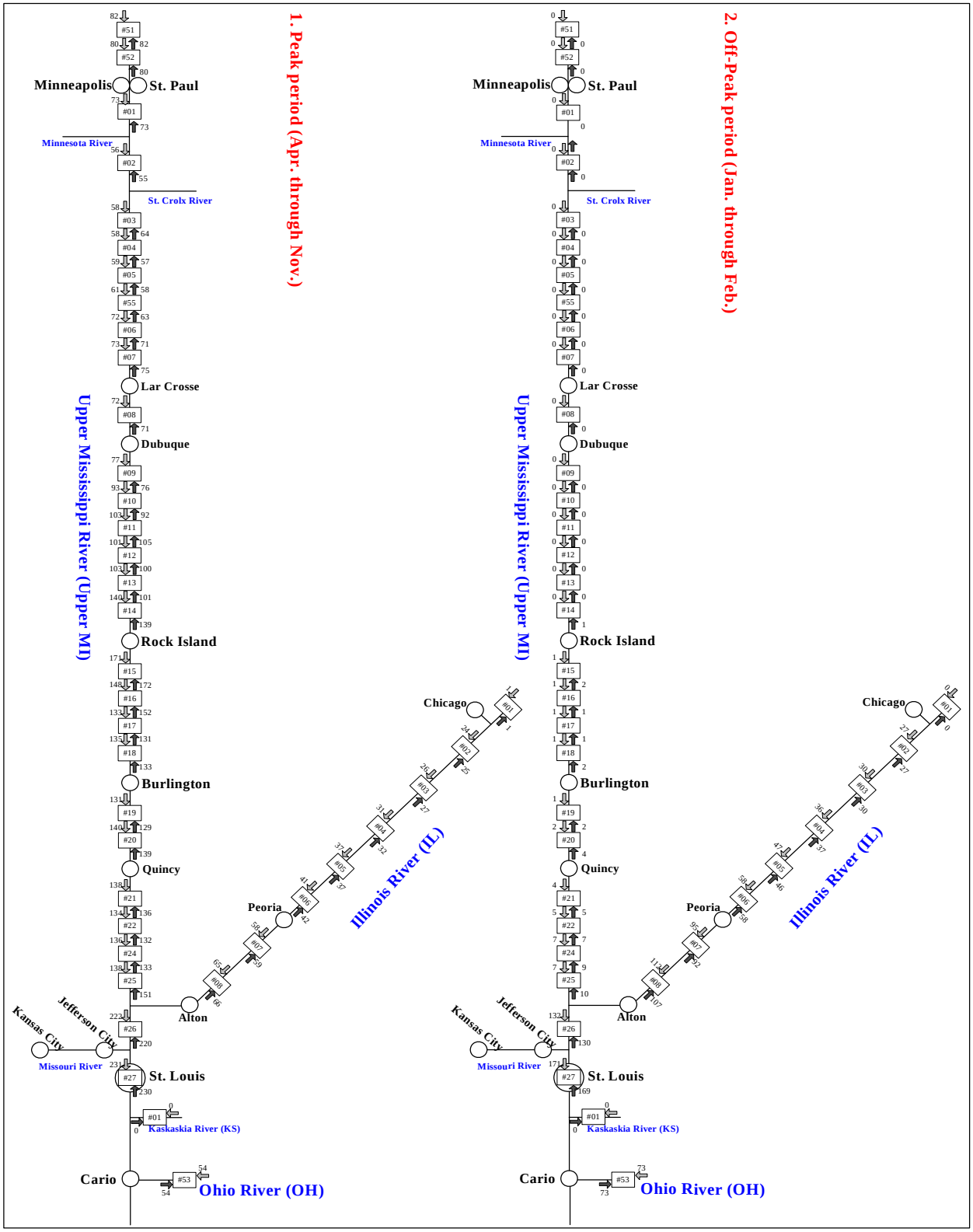

Figure 13. Average Monthly Towboat Traffic of the 90% Unique Towboats at the UMR and Illinois Locks during the UMR Peak and Off-peak (2000-2004)

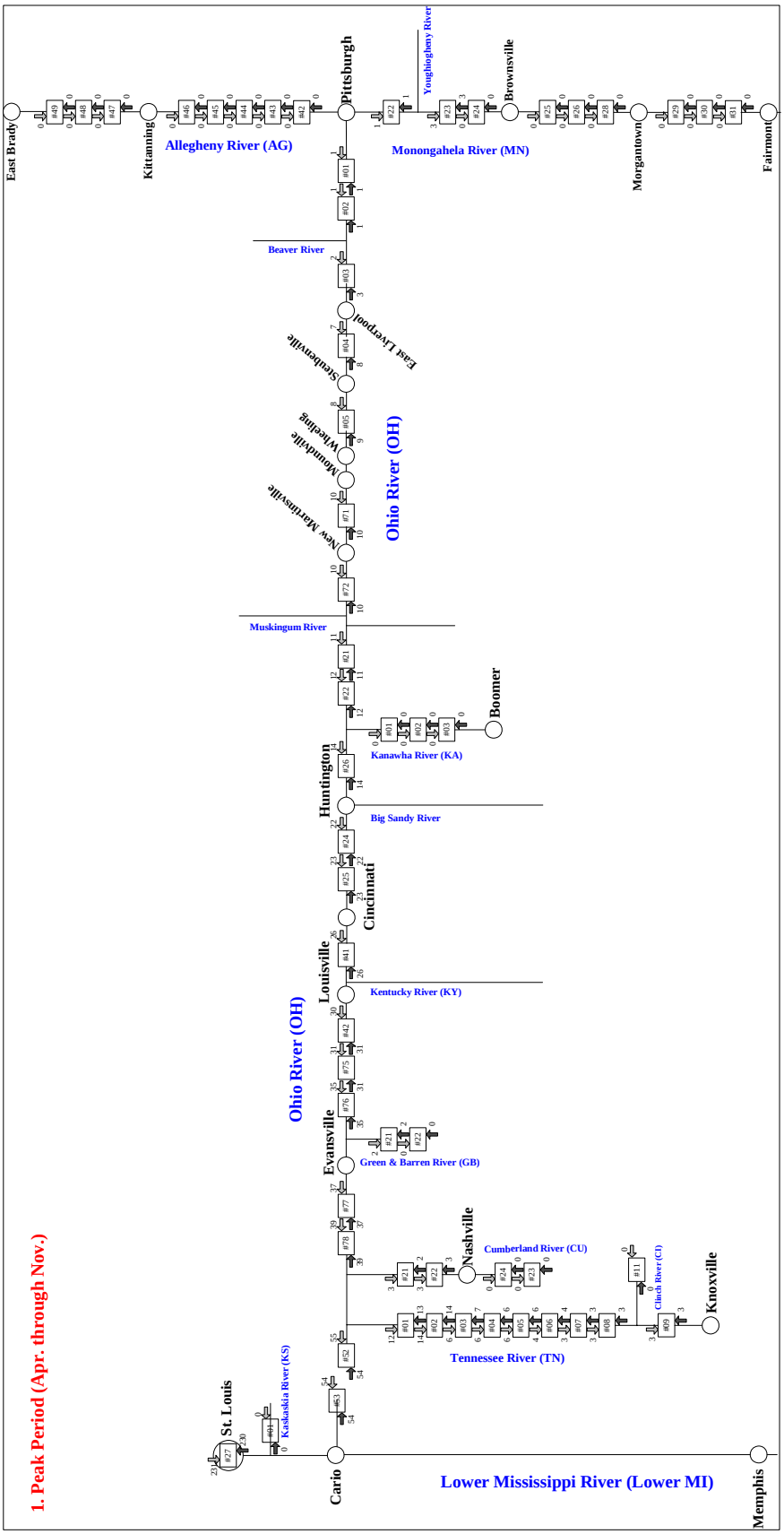

Figure 14 (a). Average Monthly Towboat Traffic of the 90% Unique Towboats at the Ohio Locks during the UMR Peak(2000-2004)

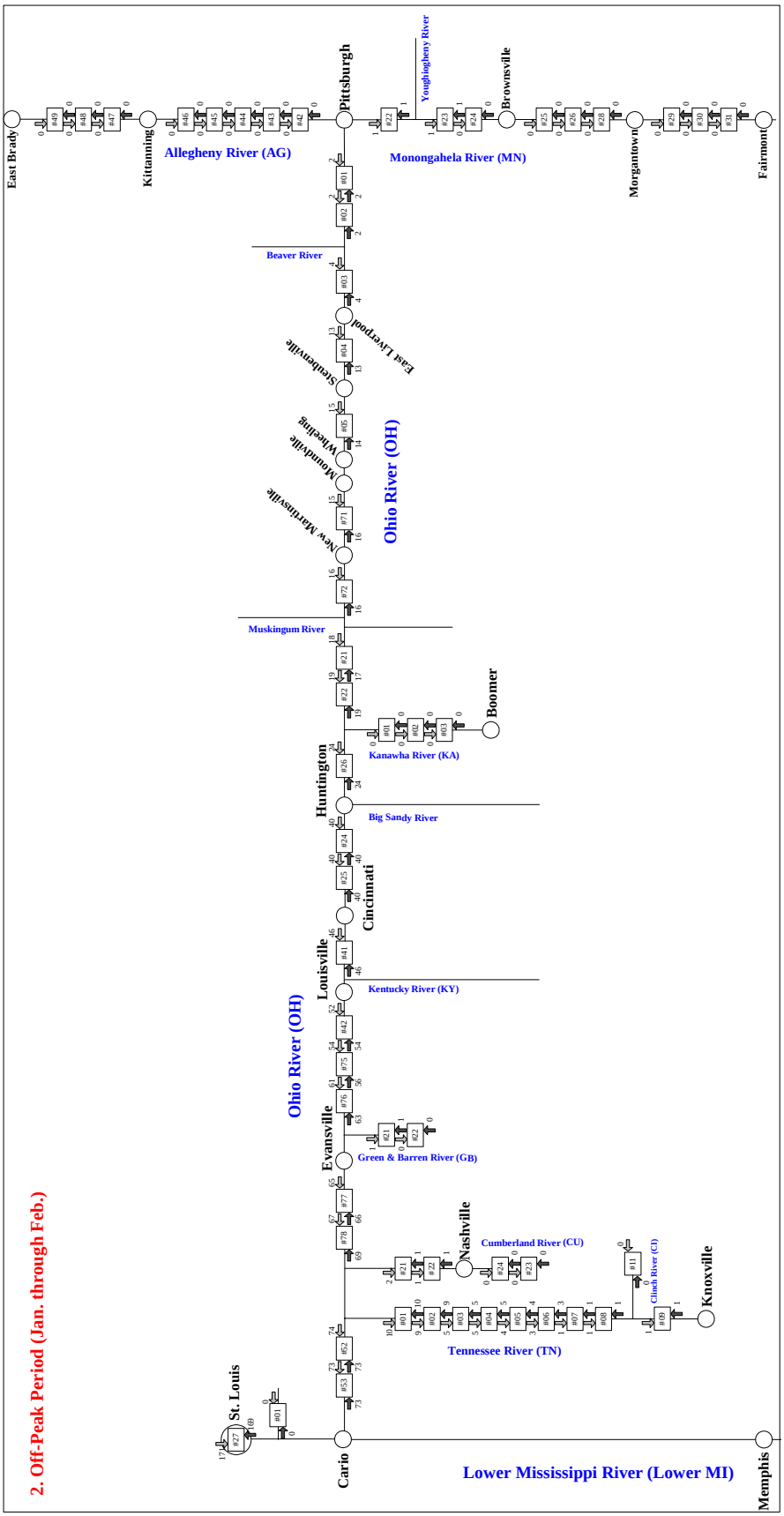

Figure 14 (b). Average Monthly Towboat Traffic of the 90% Unique Towboats at the Ohio Locks during the UMR Off-Peak (2000-2004)

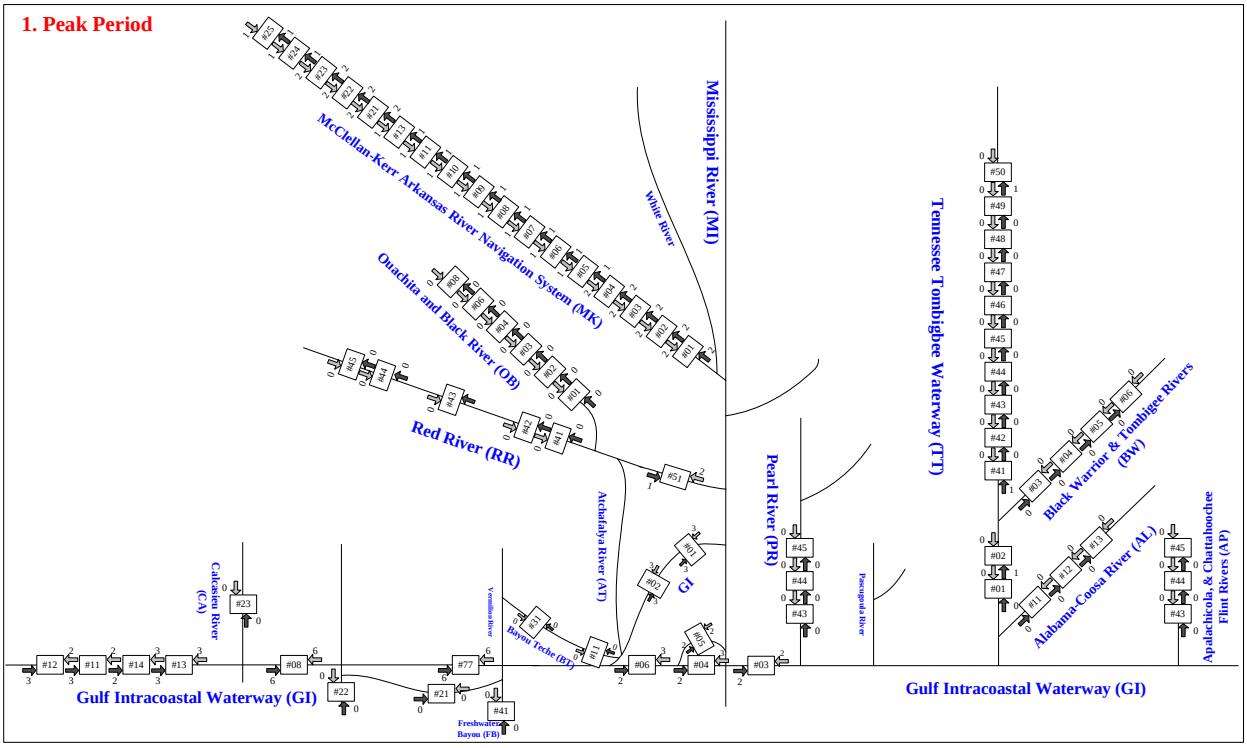

Figure 15 (a). Average Monthly Towboat Traffic of the 90% Unique Towboats in the Lower MVD, SWD, and SAD during the UMR Peak of the UMR (2000-2004)

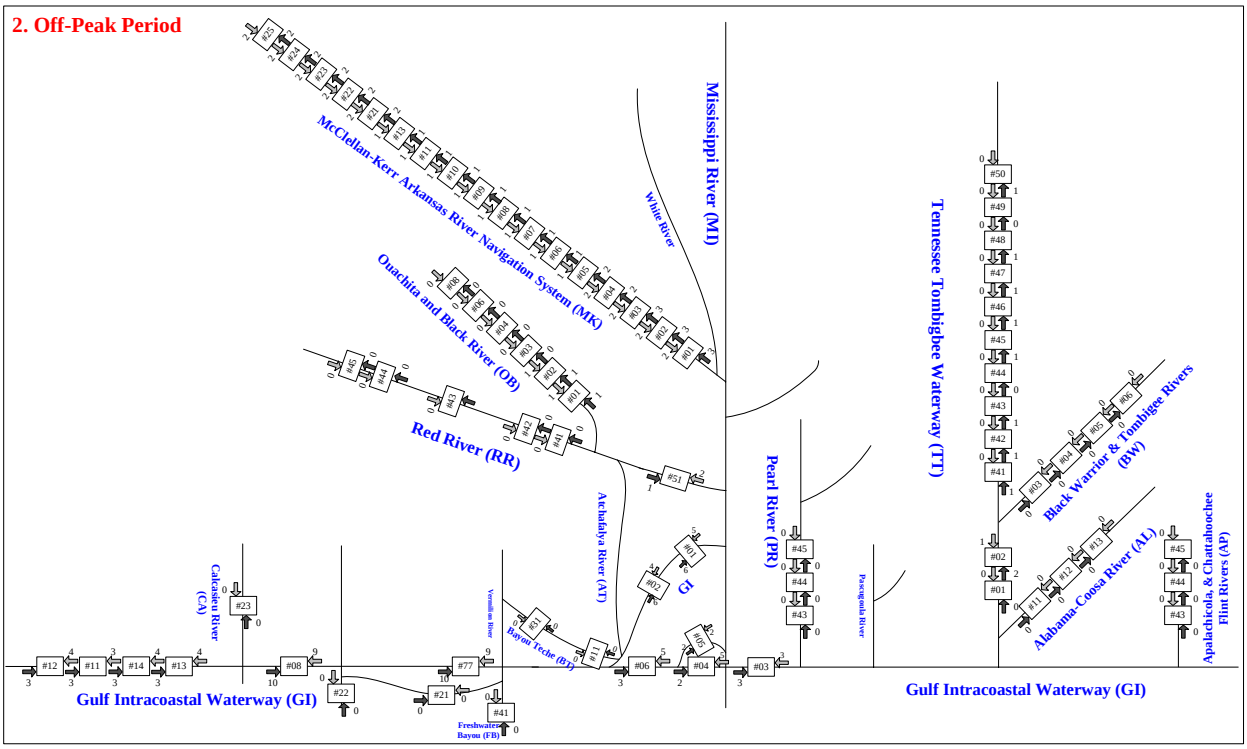

Figure 15 (b). Average Monthly Towboat Traffic of the 90% Unique Towboats in the Lower MVD, SWD, and SAD during the UMR Off-Peak (2000-2004)

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- A **microscopic event model** that will generate routes for individual shipments from commodity origin to destination in order to evaluate non-structural and reliability measures.

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