Thank you for your comment, Lynn Muench.

The comment tracking number that has been assigned to your comment is GLMRIS50623.

Comment Date: April 1, 2011 08:52:50AM
GLMRIS
Comment ID: GLMRIS50623

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Lynn M. Muench
Senior Vice President - Regional Advocacy

March 31, 2011

Mr. David Wethington
Project Manager
Chicago District, U.S. Army Corps of Engineers
111 North Canal Street
Chicago, IL 60606

RE: Great Lakes and Mississippi River Interbasin Study
National Environmental Policy Act Scoping Comments

Dear Mr. Wethington:

The American Waterways Operators is the national trade association for the tugboat, towboat, and barge industry. AWO represents 350 member companies in an industry with more than 4,000 towing vessels, more than 27,000 dry and liquid cargo barges, and over 30,000 mariners. About 20 AWO members transit through, or are based on, the Chicago Area Waterways System (CAWS). AWO appreciates the opportunity to comment on the U.S. Army Corps of Engineers' Great Lakes and Mississippi River Interbasin Study (GLMRIS) National Environmental Policy Act (NEPA) scoping process.

AWO members have demonstrated their full commitment to protecting the CAWS and Great Lakes from aquatic nuisance species (ANS) transfer through their collaborative work with the Corps and the U.S. Coast Guard as the electric dispersal barriers have been built, tested, and maintained in the Chicago Sanitary and Ship Canal over the past several years. AWO has also been an active participant, with a variety of federal and state agencies, in the investigation of whether towboats and barges could inadvertently act as vectors for the transport of fish eggs and larvae. In fact, the industry voluntarily stopped taking on and discharging ballast water across the barriers – a practice that was always rare, but is now never performed.

AWO has also provided comments on the matter of ecosystem protection to the Asian Carp Regional Coordinating Committee (ACRCC), the U.S. House Water Resources & Environment Subcommittee of the Committee on Transportation & Infrastructure, the Illinois Senate Environment Committee, the Chicago City Council, and the Corps. These comments have included recommendations on strategies to prevent Asian carp encroachment on the Great Lakes basin while preserving the waterborne commerce vital to the nation's economy. As the freight transportation mode with the greatest fuel efficiency and the smallest carbon footprint, AWO has long worked cooperatively with the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (FWS), the Council on Environmental Quality, and state environmental agencies on a wide range of environmental issues, including the recovery of threatened and endangered species and the reduction of emissions from vessel engines and tank barges.

AWO looks forward to working with the Corps to find ways to protect the ecosystem of the Great Lakes and the Mississippi River basin while preserving the free flow of waterborne commodities critical to the U.S. economy and international competitiveness. AWO's comments will focus on the scope and structure of GLMRIS, focus areas I and II, and Asian carp science, as well as other matters that we urge the Corps to consider.

Scope and Structure of the GLMRIS

AWO applauds the Corps for carefully following Congress' directive to "study the range of options and technologies available to prevent the spread of ANS between the Great Lakes and the Mississippi River basin through the Chicago and Sanitary Ship Canal (CSSC) and other aquatic pathways." The Water Resources Development Act of 2007 clearly instructs the Corps to investigate the movement of all species, including bacteria, viruses, plants, algae, invertebrates, parasites, and fish, not just Asian carp, and movement from one basin to another, not just from the Mississippi River to the Great Lakes.

AWO strongly recommends that the Corps engage industry on a regular basis, at a minimum before each decision point, to ensure that the study is taking all navigation considerations into account. The Corps would be well-advised to host bi-annual open meetings that solicit public input on the direction of GLMRIS, and should continue to make draft reports available for public comment. A transparent and vigorous process is essential to ensure an extensive, thoughtful, and complete study. The Corps should ensure that all stakeholders have the opportunity to be actively involved in the development of the study "goals, objectives, scope, and alternatives" during this and futures stages of the study. AWO also requests to be a part of the Executive Steering Committee (ESC), along with other appropriate stakeholders, or, at a minimum, all stakeholders should be permitted to observe ESC meetings, or review ESC meeting minutes in a timely manner. For the towing industry and its customers, this is especially essential for all discussions involving Focus Area I.

AWO cautions the Corps not to consider truncating the study to eighteen months. The claim that "nothing is being done" to stop the advancement of Asian carp is simply not based in reality. Last year alone, the ACRCC, a multi-state and multi-agency consortium, spent over $37 million in an organized and targeted manner to research, monitor, and control the movement of the Asian carp. The ACRCC is positioned to spend another $33 million in 2011 to continue this important and effective work. The Administration has demonstrated its commitment to ensure the success of this group with the appointment of an Asian Carp Director to lead its efforts. Shortening the GLMRIS timeline would render this study inadequate as a basis for the future public policy decisions of Congress or the Administration.

AWO encourages the Corps to continue to use "risk reduction" as a guiding principle for the study. It is the most logical and practical way to evaluate appropriate actions and most effectively allocate the scarce state and federal resources available.

To ensure that the study is as robust and inclusive as possible, AWO recommends that the Corps engage more individuals from the Mississippi River basin, including the commanding officers of the Mississippi Valley Division, the St. Louis District, and the New Orleans District. AWO member companies headquartered as far away as Houston, New Orleans, and St. Louis operate frequently through the O'Brien and Chicago locks, servicing many businesses that rely on the

cost-effective freight transportation furnished by the towing industry and the favorable, "water-compelled" rates they receive from the rail companies. Essential imports and exports, including coal for power plants, petroleum products, agricultural goods, salt, fertilizer, steel, cement, and other raw materials for construction and manufacturing, move through the CAWS and the Chicago area locks.

Focus Area I

To properly assess all aspects of the potential actions being considered on the CAWS, the Corps must produce a thorough assessment of the economic impacts of the waterborne commerce that moves on the CAWS. At this point, no such study exists. GLMRIS should examine the economic and environmental costs of severing this key commercial artery, including a review of the consequences of a modal shift, such as increased air pollution, increased traffic accidents, injuries, and fatalities, increased noise pollution, increased road maintenance, and a decreased quality of life.

Two recent studies may well help to inform the type of economic study needed. A study by the Ports of Indiana, released in September 2010, found that 17,655 jobs and $1.9 billion in economic activity in northwest Indiana alone were attributable to barge movements through the O'Brien Lock in 2008. Another study by DePaul University, published in April 2010, concluded that the conservative and preliminary economic value of the commercial navigation to the region is $4.7 billion. Both studies are appended to these comments.

Another recent study by the Texas Transportation Institute (TTI), sponsored by the U.S. Maritime Administration and the National Waterways Foundation, offers some insights into the environmental and human costs of a modal shift from waterways to rail or trucks. As an example, TTI found that a cessation of waterborne commerce in the smaller metropolitan area of St. Louis would increase the region's traffic delays by almost 500%, increase injuries and fatalities on the region's highways by up to 45%, and increase the amount of carbon dioxide pollutants from 2.1 million tons (rail) to 14.2 million tons (trucks). The TTI study is also attached.

AWO strongly cautions the Corps to not utilize the Great Lakes Commission's *21st Century Waterway Study* in the GLMRIS analysis. This document does not meet the criteria of an unbiased scientific study. Its conclusion has been laid out in its objectives: to "develop and evaluate scenarios for separation." AWO strongly recommends that the Corps avoid incorporating any project with limited scientific strength into this or any NEPA assessment.

Given the relatively low profile of the towing industry, it is easy to forget that the removal of just one barge from the waterways would add 58 trucks to the highways. CAWS and its critical waterways infrastructure must be preserved. Physical separation of the Great Lakes and Mississippi River basins is not a viable option for the economy or the environment. It is clearly not good public policy, and we believe should not be considered by GLMRIS.

Focus Area II

Every state surrounding the Great Lakes, with the exception of Michigan, contains at least one of the 36 potential surface water connections and at least one of the 18 locations at "significant risk" for transfer along the 1,500-mile continental divide identified in GLMRIS' *Other Pathways*

Preliminary Risk Characterization Report. Due to the active work directed by the ACRCC *Framework,* the CAWS is the "Fort Knox" of potential pathways, with three electric barriers, targeted rotenone applications, a variety of widespread and targeted fishing, and flood barriers preventing ANS movement between the Great Lakes and Mississippi River basins through the CAWS. Other actions that are underway or have taken place have dramatically decreased the risk of ANS transfer. Concentrating on Focus Area II, not Focus Area I, will be the most impactful way to stop the movement of the full range of ANS between the two basins.

Asian Carp Science

The Asian carp issue should not become the driving force of GLMRIS. There is no reason to conclude that there is an imminent threat of Asian carp bypassing the electric barriers and moving into the Great Lakes. Both the Supreme Court and the District Court of Illinois have rejected preliminary injunctions to close the O'Brien and Chicago locks, ruling that states and environmental groups provided no evidence that harm was imminent. In addition, the FWS believes breeding populations of Asian carp to be at least 100 miles from Lake Michigan. Most important, the single Asian carp that was caught above the electric barriers in Lake Calumet, according to forensic work, appears to have been placed there by humans.

With the large number of possible pathways for introduction of Asian carp into the Great Lakes, keeping isolated numbers or single specimens of fish out of the Great Lakes is likely an impossible task, and focusing on such a goal would be an irresponsible diversion of resources. In fact, isolated specimens of Asian carp have been found in Lake Erie for over 15 years. Isolated cases of Asian carp being discovered upriver of the control barriers do not indicate the presence of a self-sustaining population.

As the *Other Pathways Risk Characterization Report* states, recent bioenergetics models of Asian carp metabolism and Great Lakes resources availability conclude that the silver and bighead carp, which are pelagic plankton feeders, would be restricted to nutrient-rich areas of the Great Lakes including embayments and the mouths of tributaries. Additionally, it is well known that the southern portions of Lake Michigan contain limited levels of plankton. An aquatic "desert" is likely to further constrain any carp from surviving and thriving in Lake Michigan. As such, AWO supports the examination through GLMRIS of whether or not isolated numbers of Asian carp could successfully establish self-sustaining populations in Lake Michigan and the other Great Lakes.

Other Considerations

AWO also offers the following comments, questions, and suggestions for the Corps' consideration as it moves forward with GLMRIS analysis:

- "Expected Outcomes" is an unlikely and disappointing starting point for a study that should be unbiased and based on scientific information. AWO asks the Corps to outline all expected outcomes and allow comments on them before moving forward.
- Although the study cannot evaluate ANS movement across international borders, the potential for movement of ANS through other basins or watersheds should inform all possible recommended actions.

- The study should also look at other, non-aquatic pathways for the transfer of ANS between basins, especially human transfer, either deliberately or by accident, and develop preventative recommendations.
- Attachment F to the Project Management Plan, under the navigation section, includes evaluation criteria for recreational navigation benefits but not commercial navigation benefits. Commercial benefits should also be included.
- A more detailed explanation of the Consolidated Command Guidance and the ESC Memorandum of Understanding (MOU) would further inform comments and a better understanding of the study process.
- The Corps should furnish a detailed explanation of how monitoring and adaptive management will be part of the study.
- GLMRIS should promote balanced and co-equal objectives in its examination of how to prevent ANS transfer and preserve waterways uses. However, there are signs that GLMRIS either favors commercial and recreational fishing at the expense of commercial and recreational navigation, or views existing waterways uses as a study restraint. This is reflected by statements in Appendix 2, which describes the potential trade-off for each ANS alternative. The trade-off depicts the preservation of commercial and recreational fisheries as an economic benefit while commercial and recreational navigation is depicted as an economic cost of ANS mitigation measures.
- The Corps should update all current and future reports and documents to include a key for acronyms used.

AWO strongly urges the Corps to determine the scope of GLMRIS in a way that ensures a balanced approach to the recommendation of alternative ANS controls – an approach that recognizes the human uses of our nation's water resources as an intrinsic component of the nation's social and economic fabric and is cognizant of the benefits drawn from commercial uses of our water resources and infrastructure.

AWO appreciates the challenging environment in which this situation places the Corps, and would like to reiterate our interest in helping to develop and implement solutions that protect both the environment and the economy. Please don't hesitate to contact me if further information is needed. Thank you for the opportunity to comment on the scope of this important study.

Sincerely,

Lynn M. Muench

ECONOMIC IMPACTS OF WATERBORNE SHIPPING ON THE INDIANA LAKESHORE

August 2010
Calendar Year 2008

Prepared for:
PORTS OF INDIANA

Martin Associates
941 Wheatland Avenue
Suite 203
Lancaster, PA 17603

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ECONOMIC IMPACTS OF WATERBORNE SHIPPING ON THE INDIANA LAKESHORE

Study prepared by Martin Associates – August 2010
Peer Reviewed by Economics Professors from the Universities of Indiana, Notre Dame and Purdue

I. EXECUTIVE SUMMARY

Martin Associates was retained by the Ports of Indiana to measure the local, regional and state economic impacts generated by maritime activity of the Indiana Lakeshore terminals including the Port of Indiana-Burns Harbor tenant base. Economic impacts generated at the cargo and industrial facilities include the impacts generated by steel products, steel input commodities such as iron ore and coal/coke, cement, fertilizer, grain/soybean products, limestone, as well as other dry and liquid bulk cargoes. In 2008, according to the U.S. Army Corps of Engineers Waterborne Commerce Statistics, about 32 million tons of foreign and domestic cargo shipments were handled on the Indiana Lakeshore including facilities located at Burns Harbor, Indiana Harbor, Buffington Harbor and Gary (this includes 1.9 million tons that moved via the Inland Waterways System through O'Brien Lock). The majority, about 78% of this tonnage, was iron ore pellets discharged by laker vessels to the various steel mills along the Indiana Lakeshore. It should also be noted that 2008 was the most current year of data available for all shipping modes at the time of this study and that the 32 million tons of cargo handled that year were less than the previous 4-year average of 34.2 million tons. Similarly, the 1.9 million barge tons were less than the average of 3.0 million tons over the same 2004-2007 period.

The study employs methodology and definitions that have been used by Martin Associates to measure economic impacts at more than 250 ports in the United States and Canada, and at the leading U.S. airports. It is to be emphasized that only measurable impacts are included in this study. In order to ensure defensibility, the Martin Associates' approach to economic impact analysis is based on data developed through an extensive interview and telephone survey program of port tenants, lakeshore shippers and firms providing cargo and logistics services on the Indiana Lakeshore. Specific re-spending models have been developed for the Indiana area to reflect the unique economic and consumer profiles of the regional economy. To further underscore the defensibility of the study, standardized impact models, such as the MARAD Port Kit were not used. Instead, the resulting impacts reflect the uniqueness of the individual port operations, as well as the surrounding regional economy.

The Indiana Lakeshore is unique in the fact that three separate modes of waterborne commerce are currently used in the shipping and receipt of raw materials and finished product. These include: international ships moving cargo through the St. Lawrence Seaway ("salties"), lake ships moving international and domestic shipments throughout the Great Lakes ("lakers"), and barges of international and domestic cargoes moving along the Inland Waterways System. It is this unique convergence of water transportation modes that provides steel mills and other industries with the ability to use cost-effective methods for receiving raw materials such as iron ore, coal and limestone and for shipping finished products to domestic and international markets.

Without water transportation, production costs would undoubtedly increase and therefore potentially hinder future contracts and levels of manufacturing.

While the balance of this report details the economic impact of the Indiana Lakeshore waterborne shipping activity, key findings from the CY2008 analysis include the following:

Annual Economic Impact of Waterborne Shipping on Indiana's Lakeshore:

- 104,567 direct, induced, indirect and related jobs;
- $14.2 billion of economic activity to the state;
- $567 million of state and local tax revenue; and
- 17,655 jobs and $1.9 billion in economic activity attributed to Indiana barge movements through the O'Brien Lock

Economic Impacts of Waterborne Shipping Activity on Indiana's Lakeshore

*Based on economic data from CY2008**

CATEGORY	SHIP ACTIVITY (LAKER & SALTY)	BARGE ACTIVITY VIA O'BRIEN LOCK	TOTAL MARITIME SHIPMENTS
DIRECT JOBS	17,443	3,394	20,837
TOTAL JOBS	86,912	17,655	104,567
DIRECT PERSONAL INCOME	$781,620,212	$141,502,699	$923,122,911
TOTAL PERSONAL INCOME	$5,145,679,348	$890,168,403	$6,035,847,751
LOCAL PURCHASES	$1,889,242,899	$227,006,700	$2,116,249,599
TOTAL STATE & LOCAL TAXES	$483,693,859	$83,675,830	$567,369,689
TOTAL VALUE OF ECONOMIC ACTIVITY	$12,287,459,456	$1,909,005,610	$14,196,465,066

*Totals may be rounded.

This study was conducted by Martin Associates, 941 Wheatland Ave., Ste. 203, Lancaster, PA 17603.

The following university professors provided input and peer reviews of the analysis:

- *Bruce Jaffee, Professor/Chairperson, Dept. of Economics & Public Policy, Indiana University*
- *Richard Jensen, Professor of Economics, Dept. of Economics, University of Notre Dame*
- *Amlan Mitra, Professor of Economics, Dept. of Finance and Economics, Purdue University Calumet; Member, Transportation Research Board, National Academy of Sciences*

II. INTRODUCTION AND OVERVIEW

Martin Associates was retained by the Ports of Indiana to measure the local, regional and state economic impacts generated by maritime activity of the Indiana Lakeshore terminals including the Port of Indiana-Burns Harbor tenant base. Economic impacts generated at the cargo and industrial facilities include the impacts generated by steel products, steel input commodities such as iron ore and coal/coke, cement, fertilizer, grain/soybean products, limestone, as well as other dry and liquid bulk cargoes. In 2008, according to the U.S. Army Corps of Engineers (USACE) Waterborne Commerce Statistics, about 32 million tons of foreign and domestic cargo shipments were handled on the Indiana Lakeshore including facilities located at Burns Harbor, Indiana Harbor, Buffington Harbor and Gary (this includes 1.9 million tons that moved via the Inland Waterways System through the O'Brien Lock). The majority, about 78% of this tonnage, was iron ore pellets discharged by laker vessels to the various steel mills along the Indiana Lakeshore. It should also be noted that 2008 was the most current year of data available for all shipping modes and that the 32 million tons of cargo handled in 2008 was less than the previous 4-year average of 34.2 million tons. Similarly, the 1.9 million barge tons were less than the average of 3.0 million tons over the same 2004-2007 period.

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The results of the economic impact studies are used not only to identify the importance and job generation aspects of the maritime community, but the cargo impact models are used to assess the impacts of alternative master plan development recommendation, the impact of changing tonnage levels, annual updates, the impact of new cargoes/services, and the justification of capital development projects.

The Indiana Lakeshore is unique in the fact that three separate modes of waterborne commerce are currently used in the shipping and receipt of raw materials and finished product. These include: international ships moving cargo through the St. Lawrence Seaway ("salties"), lake vessels carrying international cross-lake and domestic intra-lake shipments ("lakers"), and barges moving international and domestic cargoes along the Inland Waterways System. It is this unique convergence of water transportation modes that provides steel mills and other industries with the ability to use cost-effective methods for receiving raw materials such as iron ore, coal

and limestone and shipping finished products to domestic and international markets. Without water transportation, production costs would undoubtedly increase and therefore potentially hinder future contracts and levels of manufacturing.

While the balance of this report details the economic impact of the Indiana Lakeshore waterborne shipping activity, key figures from the CY2008 analysis include the following:

Annual Economic Impact of Waterborne Shipping on Indiana's Lakeshore:

- 104,567 direct, induced, indirect and related jobs;
- $14.2 billion of economic activity to the state;
- $567 million of state and local tax revenue; and
- 17,655 jobs and $1.9 billion in economic activity attributed to barge movements through the O'Brien Lock.

1. IMPACT DEFINITIONS

The impacts are measured separately for the Indiana Lakeshore cargo activity and industrial activity. The impacts are measured in terms of:

- Jobs [direct, induced, indirect and related shipper/consignee (related users)];
- Personal income;
- Business revenue; and
- State and local taxes.

Each impact measurement is described below:

- **Direct, Induced, Indirect, Related Jobs**

  Direct jobs are those that would not exist if activity at the port cargo and lakeshore terminals were to cease. Direct jobs created by cargo activity at the maritime terminals are those jobs with the firms directly providing cargo handling and vessel services, including trucking companies, terminal operators and stevedores, members of the International Longshoremen's Association (ILA), International Union of Operating Engineers, International Brotherhood of Teamsters and United Steelworkers, vessel agents, pilots and tug assist companies.

  Induced jobs are jobs created in Indiana by the purchases of goods and services by those *individuals* directly employed by each of the terminals' lines of business. These jobs are based on the local purchase patterns of area residents. The induced jobs are jobs with grocery stores, restaurants, health care providers, retail stores, local housing/construction industry, and transportation services, as well as with wholesalers providing the goods to the retailers.

Indirect jobs are created throughout the area as the result of purchases for goods and services by the *firms* directly impacted by Indiana Lakeshore activity, including the tenants, terminal operators and the firms providing services to cargo – which includes steel, general cargo, dry bulks and liquid bulks. The indirect jobs are measured based on actual local purchase patterns of the directly dependent firms, and occur with such industries as utilities, office supplies, contract service providers, maintenance and repair, and construction.

Related shipper/consignee (related user) jobs are jobs with shippers and consignees (exporters and importers) including the state's manufacturing, farming, retail, wholesale, distribution industries, and the in-state industries supporting the movement and distribution of cargo imports and exports using the port terminals for shipment and receipt of cargo. While these impacts occur for all commodities, the majority of Indiana Lakeshore shippers and consignees impacts involve the import and export of steel, coal, grain, fertilizers, salt, limestone and miscellaneous dry and liquid bulk commodities. A large number of dependent steel users are already accounted for in the port tenant/dependent user category due to the fact that the Indiana Lakeshore's facilities, including the Port of Indiana-Burns Harbor, maintain a large steel manufacturing and processing presence.

Related jobs are not dependent upon the port marine terminals to the same extent as are the direct, induced and indirect jobs since it is the demand for the final products, which creates the demand for the employment with these shippers/consignees - not the use of a particular port or maritime terminal - and therefore these firms can and do use other ports. For example, when hurricane devastation renders a port's container and breakbulk terminals inoperable, essentially suspending operations at the port, the direct, induced and indirect jobholders are immediately affected with similar consequence. However, the jobs held with related users such as manufacturing as well as wholesale and retail distribution throughout the unaffected areas of state will continue to operate. These firms are required to find alternative ports to ship and receive cargo in order to maintain given levels of operation. Therefore, viable port operations are essential to long-term retention of import and export related jobs throughout the state.

- **Personal income impact** consists of wages and salaries received by those directly employed by port and lakeshore activity, and includes a respending impact which measures the personal consumption activity in Indiana of those directly employed as the result of Indiana Lakeshore cargo and industrial activity. Indirect personal income measures the wages and salaries received by those indirectly employed.

- **Business revenue** consists of total business receipts by firms providing services in support of the cargo activity. **Local purchases for goods and services** made by the directly impacted firms are also measured. These local purchases by the dependent firms

create the indirect impacts. Revenues from port tenants, dependent shippers and consignees and lakeshore terminals are included.

- **State and local taxes** include taxes paid by individuals as well as firms dependent upon Indiana Lakeshore cargo and industrial tenant activity.

2. METHODOLOGY

The methodological approach to this study is designed to provide highly defensible, as well as accurate results. This same methodology has been used by Martin Associates in the last 25 years to assess the economic impacts of cargo and passenger activity at more than 250 seaports including:

Los Angeles, CA	*Freeport, TX*	*Philadelphia, PA*
Long Beach, CA	*New Orleans, LA*	*Wilmington, DE*
Oakland, CA	*Texas City, TX*	*Brunswick, GA*
Portland, OR	*Baton Rouge, LA*	*Richmond, VA*
Seattle, WA	*Port Everglades, FL*	*Providence, RI*
Sacramento, CA	*Palm Beach, FL*	*Montreal, QC*
San Francisco, CA	*Miami, FL*	*Quebec City, QC*
Vancouver, BC	*Jacksonville, FL*	*Prince Rupert, BC*
Vancouver, WA	*Wilmington/Morehead City, NC*	*Halifax, NS*
Houston, TX	*Virginia/Hampton Roads, VA*	*Saint John, NB*
Corpus Christi, TX	*Baltimore, MD*	*18 U.S. Great Lakes Ports*

The impacts of the Indiana Lakeshore presented in this 2008 report were estimated based on telephone and personal interviews with 94 firms in the respective region. This represents the universe of cargo and related industrial businesses (with the exception of trucking firms) on the Indiana Lakeshore including Burns Harbor, Indiana Harbor, Buffington Harbor and Gary. It is to be emphasized that a 99% response rate was achieved from these firms located in the port as well as those on the Indiana Lakeshore reporting significant maritime cargo volumes.

In order to estimate the share of impacts in terms of lake activity (laker traffic and international cargo through the St. Lawrence Seaway) and O'Brien Lock (cargo moving by barge via the Inland Waterway System), Martin Associates estimated the percentage of waterborne tonnage throughputs by commodity as identified by the USACE for the CY2008 period. This share of lake versus O'Brien Lock tonnage was then appropriated to each commodity group and resulting lakeshore shipper/consignee, as well as commodity-specific job sectors such as terminal employees, dockworkers and maritime service providers. The results of this analysis provide an estimation of the economic impacts for lake shipments versus O'Brien Lock shipments.

The direct impacts are measured at the firm level of detail, and aggregated to develop the impacts for each of the terminals' lines of business. Each firm surveyed provided Martin Associates with detailed employment levels (both full time and part time), annual payroll, local

purchases and the residence of the employees. Additional data collected from the Indiana lakeshore terminals includes: employment, vessel and barge tonnage, vessel and barge calls, revenues and expenditures.

The induced impacts are based on the current expenditure profile of residents of Indiana as estimated by the U.S. Bureau of Labor Statistics, "Consumer Expenditure Survey." This survey indicates the distribution of consumer expenditures over key consumption categories for Indiana residents. The consumption categories are:

- Housing;
- Food at Restaurants;
- Food at Home;
- Entertainment;
- Health Care;
- Home Furnishings; and
- Transportation Equipment and Services.

The estimated consumption expenditure generated as a result of the respending impact is distributed across these consumption categories. Associated with each consumption category is the relevant retail and wholesale industry. Jobs to sales ratios in each industry are then computed for Indiana, and induced jobs are estimated for the relevant consumption categories. It is to be emphasized that induced jobs are only estimated at the retail and wholesale level, since these jobs are most likely generated in each terminal area. Further levels of induced jobs are not estimated since it is not possible to defensibly identify geographically where the subsequent rounds of purchasing occur.

The "Consumer Expenditure Survey" does not include information to estimate the job impact with supporting business services, legal, social services, state and local governments, and educational services. To estimate this induced impact, a ratio of State of Indiana employment in these key service industries to total State of Indiana employment is developed. This ratio is then used with the direct and induced consumption jobs to estimate induced jobs with business/financial services, legal, educational, governmental and other social services.

The indirect impacts are estimated based on the local purchases by the directly dependent firms, combined with indirect job, income and revenue coefficients for the supplying industries in the State of Indiana as developed for Martin Associates by the U.S. Bureau of Economic Analysis, Regional Input/Output Modeling System (RIMS II).

3. ECONOMIC IMPACT MODEL

The impacts are measured for CY2008 – based on the latest USACE data available, computer models for cargo and industrial operations have been developed to test the sensitivity of the impacts to changes in economic conditions and facility utilization. It is to be emphasized

that this study is designed to provide a framework which Ports of Indiana can use in formulating and guiding future development of shipping facilities and policies for the state of Indiana.

The cargo impact model is designed to test the sensitivity of impacts to changes in such factors as maritime tonnage levels, port productivity and work rules, new port facilities development, inland distribution patterns of cargo, number of vessel/barge calls and the introduction of new carrier service. The cargo impact model can also be used to assess the impact of developing a parcel of land as a maritime terminal versus other non-cargo land uses. Finally, the maritime cargo impact model can be used to assess the economic benefits of increased maritime activity due to infrastructure development and the opportunity cost of not undertaking specific maritime investments such as dredging, new terminal development or warehouse development.

4. SUMMARY OF RESULTS

Exhibit I-1 provides a breakdown by shipping on the lake and through the O'Brien Lock for the economic impact analysis of the maritime activity at Indiana Lakeshore facilities.

Exhibit I-1 Economic Impact of Indiana Lakeshore Waterborne Shipping Activity CY2008*

CATEGORY	LAKE ACTIVITY	THROUGH O'BRIEN LOCK	TOTAL LAKESHORE
JOBS			
DIRECT	17,443	3,394	20,837
INDUCED	23,845	4,351	28,197
INDIRECT	23,896	2,871	26,768
RELATED USER	21,728	7,038	28,766
TOTAL JOBS	**86,912**	**17,655**	**104,567**
PERSONAL INCOME			
DIRECT	$781,620,212	$141,502,699	$923,122,911
INDUCED	$2,657,039,750	$481,024,275	$3,138,064,025
INDIRECT	$994,721,789	$119,523,281	$1,114,245,071
RELATED USER INCOME	$712,297,597	$148,118,147	$860,415,744
TOTAL PERSONAL INCOME	**$5,145,679,348**	**$890,168,403**	**$6,035,847,751**
VALUE OF ECONOMIC ACTIVITY			
BUSINESS SERVICES REVENUE	$431,756,656	$371,520,213	$803,276,869
TENANT/DEPENDENT USER REVENUE	$9,761,986,933	$853,334,510	$10,615,321,443
RELATED USER OUTPUT	$2,093,715,867	$684,150,887	$2,777,866,754
TOTAL VALUE OF ECONOMIC ACTIVITY	**$12,287,459,456**	**$1,909,005,610**	**$14,196,465,066**
LOCAL PURCHASES	**$1,889,242,899**	**$227,006,700**	**$2,116,249,599**
STATE & LOCAL TAXES			
DIRECT, INDUCED AND INDIRECT	$416,737,885	$69,752,724	$486,490,609
RELATED USER TAXES	$66,955,974	$13,923,106	$80,879,080
TOTAL STATE AND LOCAL TAXES	**$483,693,859**	**$83,675,830**	**$567,369,689**

*Totals may be rounded.

In 2008, waterborne shipping at Indiana Lakeshore facilities supported 104,567 jobs in the region. Of these jobs, 20,837 jobs were directly created by cargo shipping and related industrial activities, while another 28,197 induced jobs were generated in the state as a result of local purchases made by those directly employed by Indiana Lakeshore terminals and Ports of Indiana cargo and tenant activity. In addition, there were 26,768 indirect jobs supported in Indiana as the result of $2.1 billion of local purchases. The waterborne cargo moving via the Indiana Lakeshore facilities supported 28,766 jobs throughout the State of Indiana. The majority

of these jobs were associated with the processing and movement of steel products, fertilizer, grain and dry bulk cargoes at the individual terminals.

The 20,837 direct jobs received $923.1 million of direct wage and salary income, for average earnings of $44,300 per direct employee. As a result of local purchases with this $923.1 million of direct wages and salaries, an additional $3.1 billion of income and local consumption expenditures were created in the respective regions. It is this re-spending impact that supported the 28,197 induced jobs.[1] The indirect jobs holders received $1.1 billion in personal income. Related users in the state received another $860.4 million of personal income. In total, $6.0 billion of personal income was created as the result of the Indiana Lakeshore waterborne shipping operations.

Local businesses received $803.3 million of revenue from providing services to the cargo activity. Also, the terminal operators and port tenants generated nearly $10.6 billion of revenue from processing and manufacturing activities at their facilities. In addition, $2.8 billion of output was generated throughout the state by related users using the marine terminal facilities for shipment and receipt of cargo.

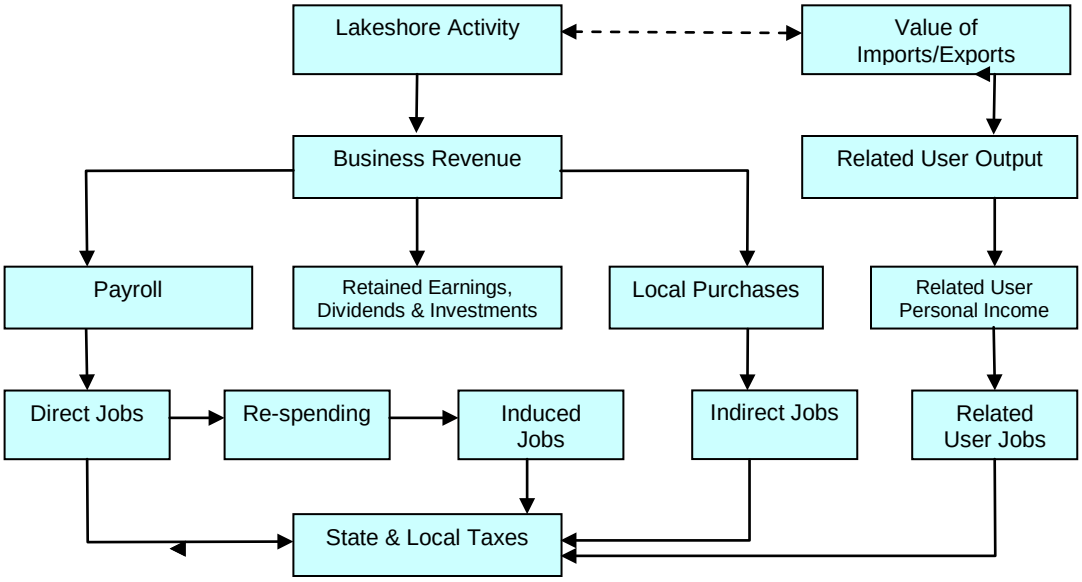
As a result of the cargo and industrial activity at the Indiana Lakeshore waterborne terminal facilities, a total of $567.4 million of state and local tax revenue was generated.

[1]The induced income impact also includes local consumption expenditures and should not be divided by induced jobs to estimate the average salary per induced job. This re-spending throughout the region is estimated using a regional personal earnings multiplier, which reflects the percentage of purchases by individuals that are made within the area. Hence, the average salary would be overestimated.

III. ECONOMIC IMPACTS OF INDIANA LAKESHORE WATERBORNE ACTIVITY

Waterborne cargo activity at a port or cargo terminal contributes to the local and regional economy by generating business revenue to local and national firms providing vessel and cargo handling services at the terminals. These firms, in turn, provide employment and income to individuals, and pay taxes to state and local governments. Exhibit II-1 shows how activity at maritime terminals generates impacts throughout the local, state and national economies. As this exhibit indicates, the impact of waterborne shipping on a local, state or national economy cannot be reduced to a single number, but instead creates several impacts. These are the revenue impact, employment impact, personal income impact, and tax impact. These impacts are non-additive. For example, the income impact is a part of the revenue impact, and adding these impacts together would result in double counting. Exhibit II-1 shows graphically how activity at the Indiana Lakeshore facilities generates the four impacts.

Exhibit II-1 Flow of Economic Impacts Generated by Maritime Activity



At the outset, activity at the maritime terminals generates business revenue for firms which provide services. This business revenue impact is dispersed throughout the economy in several ways. It is used to hire people to provide the services, to purchase goods and services, and to make federal, state and local tax payments. The remainder is used to pay stockholders, retire debt, make investments, or is held as retained earnings. It is to be emphasized that the only portions of the revenue impact that can be definitely identified as remaining in the local/regional economy are those portions paid out in salaries to local employees, for local purchases by individuals and businesses directly dependent on the port, in contributions to state and local taxes, in lease payments by tenants, and wharfage and dockage fees paid to a port.

The employment impact of port activity consists of four levels of job impacts:

- ***Direct employment impact*** -- jobs directly generated by lakeshore activity. Direct jobs generated by cargo include jobs with railroads and trucking companies moving cargo between inland origins and destinations and the terminals, longshoremen and dockworkers, steamship agents, freight forwarders, stevedores, etc. It is to be emphasized that these are classified as directly generated in the sense that these jobs would experience near term dislocation if the activity at Indiana Lakeshore maritime terminals were to be discontinued.

- ***Induced employment impact*** -- jobs created throughout the local economy because individuals directly employed due to maritime activity spend their wages locally on goods and services such as food, housing and clothing. These jobs are held by residents located throughout the region, since they are estimated based on local and regional purchases.

- ***Indirect Jobs*** -- are jobs created locally due to purchases of goods and services by firms, not individuals. These jobs are estimated directly from local purchases data supplied to Martin Associates by the companies interviewed as part of this study, and include jobs with local office supply firms, maintenance and repair firms, parts and equipment suppliers, etc.

- ***Related shipper/consignee (related user) jobs*** -- jobs with shippers and consignees (exporters and importers) supported in the state's manufacturing, agriculture, construction, energy, retail and wholesale distribution industries, and the in-state industries supporting the movement and distribution of all commodities, primarily steel, coal, grain, fertilizer, limestone and salt imports and exports using the cargo terminals. ***Related jobs are not dependent upon the marine terminals to the same extent as are the direct, induced and indirect jobs. It is the demand for the final products, which creates the demand for the employment with these shippers/consignees - not the use of a particular port or maritime terminal - and therefore these firms can and do use other ports.***

The personal earnings impact is the measure of employee wages and salaries (excluding benefits) received by individuals directly employed due to port activity. Re-spending of these earnings throughout the regional economy for purchases of goods and services is also estimated. This, in turn, generates additional jobs -- the induced employment impact. This re-spending throughout the region is estimated using a regional personal earnings multiplier, which reflects the percentage of purchases by individuals that are made within the area. The re-spending effect varies by region -- a larger re-spending effect occurs in regions that produce a relatively large proportion of the goods and services consumed by residents, while lower re-spending effects are associated with regions that import a relatively large share of consumer goods and services (since

personal earnings "leak out" of the region for these out-of-regional purchases). The direct earnings are a measure of the local impact since they are received by those directly employed by local maritime activity.

Tax impacts are payments to the state and local governments by firms and by individuals whose jobs are directly dependent upon and supported (induced jobs) by activity at the marine terminals.

1. IMPACT STRUCTURE

Economic impacts are created throughout various business sectors of the state and local economies. Specifically, four distinct economic sectors are impacted as a result of activity at the marine terminals. These are the:

- Surface Transportation Sector;
- Maritime Services Sector;
- Port Tenants, Lakeshore Terminals and Dependent Shippers/Consignees Sector; and
- Ports of Indiana (Central Office/Administration).

Within each sector, various participants are involved. Separate impacts are estimated for each of the participants. A discussion of each of the economic impact sectors is provided below, including a description of the major participants in each sector.

1.1. The Surface Transportation Sector

The surface transportation sector consists of both the railroad and trucking industries. The trucking firms and railroads are responsible for moving the various cargoes between the marine terminals and the inland origins and destinations.

1.2. The Maritime Services Sector

This sector consists of numerous firms and participants performing functions related to the following maritime services:

- Maritime Cargo Transportation;
- Vessel Operations;
- Cargo Handling; and
- Federal, State and Local Government Agencies.

A brief description of major participants in these four categories is provided below:

- Maritime Cargo Transportation: Participants in this category are involved in providing and arranging for inland and water transportation for inbound and outbound freight. For example, a freight forwarder/customshouse broker arranges for the freight to be delivered between the terminals and inland destinations, as well as the freight transportation, while the line haul barge operator provides transportation on the river system to port facilities.

- Vessel/Barge Maritime Service Operations: This category consists of several participants. The steamship agents provide a number of services for the vessel as soon as it enters a port. The agents arrange for medical and dental care of the crew, for ship supplies as well as payment of various expenses including port charges. The agents are also responsible for vessel documentation. In addition to the steamship agents arranging for vessel services, those providing the services include:

  - Chandlers - supply the vessels with ship supplies (food, clothing, nautical equipment, etc.);

  - Towing firms - provide the tug service to guide the vessel to and from port;

  - Pilots - assist in navigating the vessels to and from the maritime terminals;

  - Bunkering firms - provide fuel to the vessels;

  - Barge Fleeting/Cleaning – provide fleeting services for barges at the terminals;

  - Marine surveyors - inspect the vessels/barges and the cargo; and

  - Shipyards/marine construction firms - provide repairs (either emergency or scheduled) as well as marine pier construction and dredging.

- Cargo Handling: This category involves the physical handling of the cargo at the terminals between the land and the vessel/barge. Included in this category are the following participants:

  - Longshoremen & dockworkers - include members of the International Longshoremen's Association (ILA), International Union of Operating Engineers, International Brotherhood of Teamsters and United Steelworkers as well as those dockworkers with no union affiliation that are involved in the loading and unloading of cargo from the vessels/barges, as well as handling the cargo prior to loading and after unloading;

- Stevedoring firms - manage the longshoremen and cargo-handling activities;

- Cargo terminal operators - provide services to operate the maritime terminals, track cargo movement and provide security where cargo is loaded and off-loaded;

- Warehouse operators - store cargo after discharge or prior to loading and consolidate cargo units into shipment lots. In many cases, the freight forwarders and consolidators are also involved in warehousing activity.

- Foreign Trade Zone (FTZ) tenants - operate facilities in the Ports of Indiana Foreign Trade Zone.

- Government Agencies: This service sector involves federal, state and local government agencies that perform services related to cargo handling and vessel/barge operations at the port. Department of Homeland Security (DHS), which includes Customs and Border Protection (CBP), U.S. Immigration and Customs Enforcement (ICE) and U.S. Coast Guard, U.S. Department of Agriculture (grain inspection) and the U.S. Army Corps of Engineers (USACE), are involved. These services are provided by the government offices located in the Great Lakes region.

1.3. Port Tenants, Lakeshore Terminals and Dependent Shipper/Consignees Sector

Port tenant and lakeshore terminals jobs consist of jobs with dependent shippers/consignees that operate cargo terminals on the Indiana Lakeshore including steel mills and petroleum refineries as well as port tenants shipping and receiving cargo through the cargo terminals at the Port of Indiana-Burns Harbor facilities. The Ports of Indiana is unique in the fact that many of the tenants of each facility, specifically at Burns Harbor, are users of the waterborne cargo handled at the ports docks. Furthermore, many of the operations performed by these tenants, specifically in the steel manufacturing and steel processing are inter-dependent of each other. It is to be noted that only a portion of the raw materials and finished products used and produced by the port's tenants is received/shipped via vessel or barge. There is also a large portion of this cargo that enters/leaves the port via rail and truck. However, the advantage of having access to the Great Lakes and Inland River System with the low-cost option of vessel and barge shipments, as well as the presence of other complementary tenants, is a key attribute in attracting and maintaining such a strong tenant base at Ports of Indiana facilities. The Ports of Indiana has, over the years, been successful in creating a steel processing campus at Burns Harbor, and therefore, for the purpose of this analysis, all of the port tenant jobs are included.

1.4. Ports of Indiana

The Ports of Indiana includes those individuals employed by the port whose purpose is to oversee port activity at the port's cargo and industrial terminals.

2. COMMODITIES INCLUDED IN THE ANALYSIS

A major use of an economic impact analysis is to provide a tool for terminal development planning. As a port or terminal grows, available land and other resources for facilities become scarce, and decisions must be made as to how to develop the land and utilize the resources in the most efficient manner. Various types of facility configurations are associated with different commodities. For example, containers, automobiles and RO/RO require a large amount of paved, open storage space, while certain types of breakbulk cargoes such as steel coils, lumber and plywood may require covered storage. Perishable commodities require temperature controlled warehouses and some dry bulk cargo requires covered storage and special dust removing equipment, while tank farms are needed to store liquid bulk cargo.

An understanding of the commodity's relative economic value in terms of employment and income to the local community, the cost of providing the facilities, and the relative demand for the different commodities is essential in making future development plans. Because of this need for understanding relative commodity impacts, economic impacts are estimated for the following commodities handled at the public and private cargo terminals:

- STEEL COILS;
- IRON ORE;
- WIRE/STRUCTURAL STEEL;
- STEEL SLABS;
- COAL/COKE;
- PROJECT CARGO/MISCELLANEOUS BREAKBULK;
- GRAIN/SOYBEANS;
- BULK METALS/SCRAP;
- FERTILIZER;
- PETROLEUM PRODUCTS;
- CEMENT;
- LIMESTONE/OTHER DRY BULK;
- SALT; AND
- OTHER LIQUID BULKS.

It should be emphasized that commodity-specific impacts are not estimated for each of the economic sectors described in the last section. Specific impacts could not be allocated by individual commodities with any degree of accuracy for maritime construction, ship repair, or the state and federal government due to the fact that it is difficult to estimate the percentage of resources that are dedicated to one commodity over another. For example, maritime construction may occur at a terminal that is multi-use and cannot be attributed to a specific commodity. Similarly, law enforcement and security operations cannot be attributed to a single commodity.

3. MARITIME CARGO EMPLOYMENT IMPACTS

Employment generated by maritime cargo activity at the Indiana Lakeshore is estimated.

- First, the total employment that is in some way related to the activities at the individual ports is estimated from the interview process of 94 Indiana Lakeshore terminals, Port of Indiana tenants and service providers as well as data provided by the Ports of Indiana as described in the methodology;

- Second, the subset of total employment that is judged to be totally dependent (i.e., direct jobs) on port activity is analyzed as follows:

  - The direct job impact is estimated by detailed job category, i.e., trucking, dockworkers, barge operators, steamship agents, chandlers, surveyors, etc;

  - The direct job impact is estimated for each of the key commodities/commodity groups;

  - The direct job impact is estimated based on the residency of those directly employed;

- Induced and indirect jobs are estimated;

- Finally, jobs related to the maritime activity at the cargo terminals are described.

It is estimated that 104,567 jobs are directly or indirectly generated by activities at the cargo terminals on the Indiana Lakeshore. Of the 104,567 jobs:

- 20,837 jobs are directly generated by activities at the cargo terminals and if such activities should cease, these jobs would be discontinued over the short term.

- 28,197 jobs (induced jobs) are supported by the local purchases of the 20,837 individuals directly generated by port activity at the cargo terminals. An additional 26,768 indirect jobs were supported by $2.1 billion of purchases in the local and regional economy by firms providing direct cargo handling and vessel/barge services.

- 28,766 jobs are related to inbound and outbound cargoes through Indiana Lakeshore facilities. These jobs are supported in the state's steel processing, manufacturing, farming, construction, retail, wholesale and distribution industries, and the in-state industries supporting the movement and distribution of all commodities, primarily concentrated with steel, coal, grain, limestone, salt and fertilizer cargo imports and exports using the Indiana Lakeshore terminals.

3.1. Direct Maritime Cargo Jobs

In CY2008, about 32 million tons of domestic and foreign waterborne cargo moved via the Indiana Lakeshore terminals in Burns Harbor, Indiana Harbor, Buffington Harbor and Gary. As a result of this activity, 20,837 full-time jobs were directly created[2]. These jobs would vanish immediately if shipping operations on the Indiana Lakeshore were to cease. About 16 percent of the direct jobs are attributed to cargo activity moving into the Inland Waterway System through the O'Brien Lock.

3.2. Induced Jobs

The 20,837 directly employed individuals due to activity at the cargo terminals received wages and salaries, a part of which was used to purchase local goods and services such as food, housing, clothing, transportation services, etc. As a result of these local purchases, 28,197 jobs in the regional economy were supported. The majority of the induced jobs are with local and regional private sector social services, business services, educational services and state and local government agencies, followed by jobs in the food and restaurant sector, and then jobs in the construction and home furnishings sector.

3.3. Indirect Jobs

In addition to the induced jobs generated via purchases by directly employed individuals, the firms providing the direct services and employing the 20,837 direct jobs make local purchases for goods and services. These local purchases by the firms dependent upon the cargo facilities generated additional local jobs – indirect jobs. Based on interviews, these firms made $2.1 billion of local and in-state purchases. These direct local purchases created an additional 26,768 indirect jobs in the local economy.

3.4. Related User (Shipper/Consignee) Jobs

It is estimated that 28,766 jobs are supported in Indiana with shippers/consignees that use the Indiana Lakeshore facilities. To estimate the related user impact for cargo, the average value per ton of imports and exports was estimated using U.S. Maritime Administration, Foreign Trade Statistics and Ports of Indiana. The employment to value of output coefficient for the retail sector related to the exported and imported cargoes was then computed from Bureau of Economic Analysis, Regional Input-Output Model for the State of Indiana.

For breakbulk cargoes, the associated consuming and producing industries were identified with each commodity. For example, for imported iron and steel products, relationships were developed to convert the dollar value of these imported materials into a dollar value of

[2] Jobs are measured in terms of full-time worker equivalents. If a worker is employed only 50 percent of the time by activity at a cargo terminal, then this worker is counted as .5 jobs.

output in the key consuming industries, which include construction and metal fabrication. Relationships between the values of inputs to the value of outputs in these industries were estimated using data from the U.S. Bureau of Census, Census of Manufacturing and Census of Construction. These ratios were then used to convert the dollar value of the imported breakbulk and bulk cargoes into a dollar value of output in the consuming industries in the state. Using the respective jobs to value of output multipliers for these industries from the Bureau of Economic Analysis, Regional Input-Output Modeling System (RIMSII) model, the value of the breakbulk and bulk cargoes moving via the maritime terminals and remaining in (or produced in) the State of Indiana was converted into related shipper/consignee jobs with these users and associated supporting industries within the state. A similar methodology was used in estimating related user jobs for agricultural products.

Finally, the direct, induced and indirect maritime sector job impacts (lakeshore shippers, port companies and dependent shippers) associated with each of the cargoes for which related shipper/consignee jobs were estimated were subtracted from the total related jobs (by commodity and cargo type) to avoid double counting. The related shipper/consignee jobs include job impacts at each stage of handling the imported and exported cargo, such as the port activity, the trucking activity and the rail activity used to move the cargo to and from the lakeshore terminals and the induced and indirect jobs associated with the direct terminal activity.

4. TOTAL ECONOMIC OUTPUT, BUSINESS REVENUE, INCOME AND TAX IMPACTS

The 32 million tons of steel, general cargo and bulk (dry and liquid) cargo handled at the Indiana Lakeshore cargo terminals included in the study generated revenue for firms in each of the economic sectors. For example, revenue is received by the railroads and the trucking companies within the surface transportation sector as a result of moving export cargo to the lakeshore terminals and distributing the imported commodities inland after receipt at the cargo terminals. The firms in the maritime services sector receive revenue from arranging for transportation services, cargo handling, providing services to vessels/barges and repairs to vessels/barges calling on the terminals. The Ports of Indiana receives revenue from terminal leases and port charges such as wharfage and dockage assessed on cargo and vessels. In addition, revenue is received by dependent shippers/consignees from the sales of cargo shipped or received via the cargo terminals and from the sales of products made with raw materials received through the terminals. Since this chapter is concerned with the revenue generated from providing maritime services, the shipper/consignee revenue (i.e., the value of the cargo shipped or received through the lakeshore terminals, as well as the value of the products produced by the port-dependent shippers/consignees) will be excluded from the remaining discussion.

The revenue generated by port and lakeshore terminal activity consists of many components. For example, gross revenue is used to pay employee salaries and taxes. It is also distributed to stockholders of the companies providing the vessel and cargo handling services, and it is used for the purchases of equipment and maintenance services. Of these components,

only three can be isolated geographically with any degree of accuracy. These are the personal income component of revenue, which can be traced to geographic locations based on the residence of those receiving the income, the payment of state and local taxes, and the local purchases made by firms dependent upon the maritime activity. The balance of the revenue is distributed in the form of payments to firms located outside the State of Indiana providing goods and services to the economic sectors and for the distribution of company profits to shareholders. Many of these firms and owners are located outside of the State of Indiana and, thus, it is difficult to trace the ultimate location of the distributed revenue (other than personal income, taxes and local purchases). The value of output created by in-state related shippers/consignees of the port is attributed to the State of Indiana, and the local purchases from other firms within the state are also included in this user output measure, as defined by the in-state output coefficients (for the user industries) developed from the U.S. Bureau of Economic Analysis, Regional Input-Output Modeling System (RIMSII).

The revenue impact is a measure of the ***total economic activity*** in the state that is generated by the cargo moving via the Indiana Lakeshore. In 2008, maritime cargo and port industrial activity on the Indiana Lakeshore generated a total of $14.2 billion of total economic activity in the state. Of the $14.2 billion, $803.3 million is the direct business revenue received by the firms directly dependent upon the terminals and providing maritime services and inland transportation services to the cargo handled at the maritime terminals and the vessels calling on the terminals, while another $10.6 billion of revenue is generated by the lakeshore shippers, port tenants and on-site dependent shippers/consignees. The remaining $2.8 billion represents the value of the output to the State of Indiana that is created due to the cargo moving via the port and lakeshore terminals. This includes the value added at each stage of producing an export cargo, as well as the value added at each stage of production for the firms using imported raw materials and intermediate products that flow via the marine terminals and are consumed by industries within the State of Indiana.

5. PERSONAL EARNINGS IMPACT

The income impact is estimated by multiplying the average annual earnings (excluding benefits) of each port participant, i.e., truckers, steamship agents, pilots, towing firm employees, longshoremen, warehousemen, etc., by the corresponding number of direct jobs in each category. The individual annual earnings in each category multiplied by the corresponding job impact resulted in $923.1 million in personal wage and salary earnings. It is important to emphasize that the average annual earnings of a marine terminal-dependent job is about $44,300. By comparison, based on data supplied by the Bureau of Labor Statistics (BLS), the average wage earner in Indiana in Q1 2009 was $739/week or annual 52-week average of $38,428. Therefore, these relatively high paying jobs will have a much greater economic impact in the local economy through stimulating induced jobs than will a job paying lower wages.

The impact of re-spending this direct income for local purchases is estimated using a personal earnings multiplier. The personal earnings multiplier is based on data supplied by the

Bureau of Economic Analysis (BEA), Regional Input-Output Modeling System (RIMS II). The BEA estimates that for every one dollar earned by direct employees generated by activity at the cargo terminals, an additional $3.39 of personal income and consumption expenditures would be created as a result of re-spending the direct income for purchases of goods and services produced locally. Hence, a personal earnings multiplier of $4.39 was used to estimate the total income and consumption impact of $3.1 billion, inclusive of the re-spending effect. This additional re-spending of the direct income generates the 28,197 induced jobs.

The 26,768 indirect job holders earned $1.1 billion in indirect wages and salaries. The 28,766 related shipper/consignee jobs tied to cargo moving via marine terminals received about $860.4 million of personal income.

Therefore, the total personal income impact and consumption impact created by Indiana Lakeshore cargo shipments and related industrial activity is estimated at $6.0 billion.

6. TAX IMPACTS

State and local tax impacts are based on per employee tax burdens which are developed at the county, local and state jurisdictional levels. These tax per employee burdens are essentially tax indices that are used to allocate total taxes at each level of government to economic activity generated by the cargo terminals. To estimate the per employee tax indices, total taxes received at each governmental level in Indiana was developed from the Tax Foundation, which reports total state and local taxes from all sources as a percent of total personal income.

Cargo and marine terminal activity generated $486.5 million of state, county and local taxes. As a result of the economic activity created by the related shipper/consignees, an additional $80.9 million of state and local taxes were generated for a total cargo tax impact of $567.4 million.

APPENDIX A: PEER REVIEW LETTERS

INDIANA UNIVERSITY

KELLEY
School of Business

July 9, 2010

Mr. Jody W. Peacock
Director of Corporate Affairs
150 W. Market Street, Suite 100
Indianapolis, IN 46202

RE: Economic Impacts of the Ports of Indiana
Economic Impacts of Waterborne Shipping on the Indiana Lakeshore

Dear Mr. Peacock,

I would like to thank you and the Ports of Indiana for the opportunity to review these studies. Overall, I think they are carefully designed studies following standard economic impact approaches. I found the studies to be well written and organized. I am very impressed that Martin Associates was able to get such a high response rate from the firms that they interviewed. The location specific data provided by phone interviews coupled with Martin Associates' knowledge of the maritime industry enhance the accuracy of these results.

During my review of these studies, I provided comments and suggestions for a few specific areas including the explanations of economic models used in the analysis, types of data collected for the study, RIMS II modeling considerations, evaluation of related user jobs, and historical comparisons with 2009 data, especially because that was a recession year.

I personally have conducted economic impact studies of various individual events (e.g., the Indianapolis 500 and the Final Four basketball tournament) and industries. As a result, I feel qualified to recognize methodologically appropriate studies such as these.

Sincerely,

Bruce L. Jaffee
Professor and Chairperson

BLJ:rg

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Peer Review Letter of Endorsement

To Whom It May Concern:

I reviewed and provided comments on of the following studies:
"Economic Impacts of the Ports of Indiana," and
"Economic Impacts of Waterborne Shipping on the Indiana Lakeshore."

I provided suggestions for improvement during the process, including adding more explanations for various complex issues and terms which are well-known to economists, but might seem mysterious to the non-specialist. These suggested changes were incorporated into the final versions of these studies, which I also have thoroughly reviewed.

These studies use standard, well-accepted techniques to measure the economic benefits that result from the operations of the ports of Indiana. There is nothing controversial about the methodology used. The studies also use only data that is readily available, so their results can be easily replicated by anyone who wants to verify them.

My expertise in this area of economics arises from 30 years of conducting and publishing original research and teaching in the area of industrial economics. For the last 17 years I have served on the editorial board of the *International Journal of Industrial Organization*, an academic journal that publishes peer-reviewed studies on industrial economics. For the last six years I have served as a co-editor, making final decisions about which articles this journal publishes.

In summary, Martin Associates appears to have extensive experience in conducting studies of the economic benefits of maritime activities, and uses best-practice empirical methods and data in these studies. The results are presented clearly and should provide valuable information for future discussions of the economic benefits of maritime shipping for the State of Indiana.

Richard A. Jensen
Professor of Economics
Department of Economics
University of Notre Dame

PURDUE
UNIVERSITY
CALUMET

SCHOOL OF MANAGEMENT

July 12, 2010

Peer Review Letter of Endorsement

Ladies and Gentlemen,

I am very pleased to review the economic impact studies conducted by Martin Associates for the Ports of Indiana titled:

- Economic Impacts of the Ports of Indiana
- Economic Impacts of Waterborne Shipping on the Indiana Lakeshore

The studies focused on the local, regional, and state economic impacts generated by maritime and industrial activities for two different areas: 1) The state's three public ports located at Burns Harbor, Jeffersonville, and Mount Vernon; and 2) Indiana's Lake Michigan shoreline. Direct, indirect, and induced impacts of jobs, personal income, business revenue, and tax revenue were measured. The various exhibits demonstrate the flow of economic impacts generated by maritime activities at the various terminals of the Ports of Indiana and the Indiana Lakeshore. The overall reports show the significant economic impacts these activities have on Indiana's economy.

My background and expertise are in the fields of transportation and economic development. My past research experience includes economic impact studies of the transportation, distribution and logistics industry in Northwest Indiana. Currently, I am working on projects focusing on the estimation of economic impacts of improved freight reliability and security and of natural and man-made disruptions to inter-modal freight systems. The economic impacts of the Ports of Indiana are an integral component of the total economic impacts in the Indiana freight network system.

Based on my review of this material, I made several observations and suggestions that were included in the study related to the sections on direct and induced impacts. I have reviewed both final reports and can endorse these studies as sound measurements for the economic impacts of the Ports of Indiana and the Indiana Lakeshore shipping activities.

Please do not hesitate to contact me if you have any questions. Thank you.

Respectfully submitted by:

Amlan Mitra, Ph.D.
Professor of Economics
Department of Finance and Economics
Member, Transportation Research Board, National Academy of Sciences

AN ANALYSIS OF THE ECONOMIC EFFECTS OF TERMINATING OPERATIONS AT THE CHICAGO RIVER CONTROLLING WORKS AND O'BRIEN LOCKS ON THE CHICAGO AREA WATERWAY SYSTEM

April 7, 2010

DEPAUL UNIVERSITY

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Executive Summary

Concern about the migration of Asian Carp into the Great Lakes system has been the impetus for discussion about terminating operations at three facilities in the Chicago Area Waterway System: the Chicago Controlling Works, the Thomas J. O'Brien Lock and the Wilmette Pumping Station. To foster understanding about the implications of this method of partial ecological separation, this study explores the extent of the economic activity that would be affected by these actions and their potential influence on the region's economic wellbeing.

The findings show that spending by consumers and commercial shippers on the barge and boat operations that would be affected by closure of the locks has an annual financial impact of $1.3 billion. This figure is inclusive of multiplier effects related to waterway use but not inclusive of certain employment-related effects, which can only be measured with further study. The economic value lost from permanent closure is estimated to be $582 million the first year, $531 annually over the subsequent seven years, and $155 million annually thereafter. The net present value of these costs, over a 20-year planning horizon at a four percent discount rate, is $4.7 billion.

For the first year after closures, the lost value consists of added transportation costs ($125 million; inclusive of social costs), losses to recreational boaters ($5 million), consumers of river cruises and tours ($20 million), municipal departments providing public protection ($6 million), property owners ($51 million), and regional agencies needing additional funds for flood-abatement systems ($375 million). A portion of these losses would be shouldered by industries outside the Chicago metropolitan area, particularly certain ports in the Mississippi River basin that serve the barge transportation industry.

Additional research is needed to develop more accurate estimates in a variety of areas, including the effects of closure on assets and activities that derive their value from the aesthetic qualities of the river system, such as riverfront property, boat tours and cruises. This study also does not consider the employment-related effects, which will require separate study. Nonetheless, it offers a framework to illustrate how closure would affect various sectors of the economy, and offers suggestions for a more detailed study that could be conducted in the future.

I. Introduction

The prevalence of two species of Asian Carp in the Chicago Area Waterway System (CAWS) is generating vigorous debate about how to prevent a sustainable population from making its way into the Great Lakes System. A variety of alternatives, including greater use of pesticides, additional "electronic fencing", modified lock operations, and complete hydrologic separation have been proposed to lessen the possibility of this occurring. One method of partial hydrologic separation under review involves the permanent cessation of operations at the Chicago Controlling Works ("Chicago Lock"), the Thomas J. O'Brien Lock, the locks' accompanying sluice gates, and the Wilmette Pumping Station.

This paper focuses on the potential economic effects of the latter alternative. It offers economic and financial estimates of the impact terminating operations at these facilities would have in two areas relevant to the policymaking process. First, it provides estimates of the aggregate spending by consumers and commercial shippers on goods and services directly tied to marine vessels that would be directly and indirectly affected by closing the locks. Second, it estimates the economic value that would be lost from closure, through reductions in consumer surplus, diminished land value, and costs imposed on government agencies. This second section also illustrates how costs are distributed between consumers and institutions, as well as how these losses would be spread out over time.

To formulate these estimates, this study draws primarily on existing data and scholarly research that has been subject to professional review. In areas where little or no published research exists regarding the probable impact closure would have on metropolitan Chicago, it reviews the economic valuation and "benefit transfer" literature to identify measurements made in comparable settings in other parts of the country that can be appropriately applied to this region.

There is a particular dearth of published information about how recreational activities involving use of locks affect the metropolitan economy. Previous studies on recreational boating evaluate the CAWS and the Great Lakes as an integrated unit rather than as distinct resources to be evaluated separately. Similarly, prior studies tend to focus on single aspects of the waterway system, such as recreation, commercial shipment, or flood-abatement. For example, the Illinois Terminal Port District commissioned a study in 2003 that showed more than 8,500 jobs are directly or indirectly linked to the Port of Chicago. Although these studies are useful, they do not provide the U.S. Army Corps of Engineers (USACE) with the full range of analysis needed to evaluate the costs of alternatives related to preventing carp from entering the Great Lakes.

The author and research contributors acknowledge that preparing the estimates for this study required dealing with a great deal of uncertainty. It was not possible to expand the scope of the study to include the collection of extensive primary data, and it was necessary to make informed judgments about variables that have not been accurately quantified in the past, such as

the mix of boats that use the river system. In some areas, we base our estimates on information provided informally by professionals involved with the regional waterway system. Nonetheless, we have attempted to make our assumptions and calculations as transparent as possible, and make available a "computational spreadsheet" on the Chaddick Institute web site to help readers understand the nature of our analysis.

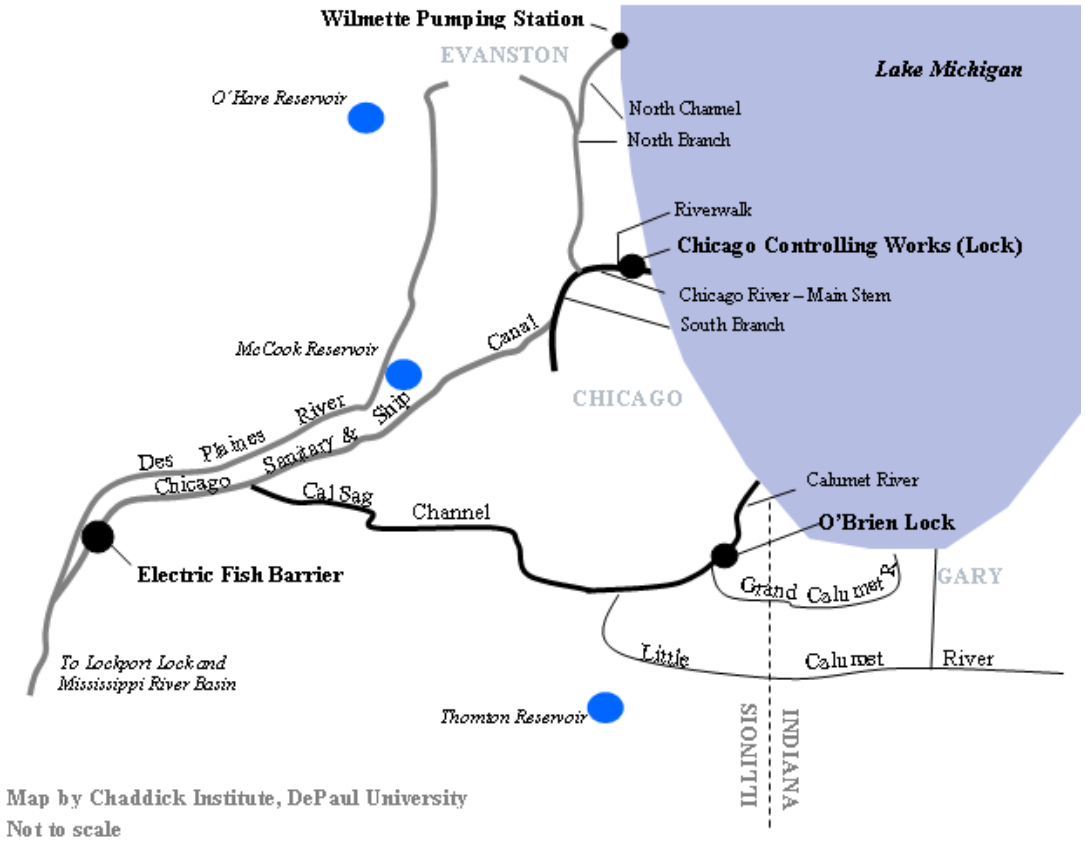
Although we evaluate a broad range of economic activities in this paper, some of the most significant effects of closing the locks are beyond our scope. We do not estimate, for example, the possible declines in the value of specialized transportation equipment and facilities, and the potential induced effects of changing shipping patterns on employment at suppliers of barge services. Nor do we estimate the probable changes in tax revenue to municipal governments or how changing water quality may affect the demand for river-oriented recreation, such as paddling trips and fishing trips. Considering that commodities and products valued at an estimated $16 billion move through CAWS annually, and that river property within 800 feet of the shoreline has a market value of $10.22 billion (see discussion in Section III), more research is needed to understand the full effects of lock closing.

II. Background Perspective

For more than 160 years boat traffic has moved through a system of natural and man-made inland waterways linking the Great Lakes and Mississippi River basins together. Starting in 1849, commerce flowed through an elaborate system of rivers and lakes including the 96-mile Illinois & Michigan Canal. The present day Chicago Lock, located roughly one-half mile east of the Michigan Avenue Bridge, was built in 1898 to replace an older lock in this system and to support the impending reversal of the flow of the Chicago River.

In 1900, the river's reversal was achieved with the opening of major portions of the Chicago Sanitary & Ship Canal (CSSC) on the southwest side of the city, which provided a more expedient passage for boats, better sanitation, and increased flood control in the region. Boats navigating the Chicago River's Main Stem and South Branch, the CSSC, the Des Plaines River, and the Illinois River now traveled downstream the entire distance, from Lake Michigan to the Mississippi River basin, and the original canal was eventually abandoned. Another improvement, the North Shore Channel, was completed between Chicago and Wilmette in 1920 to support flood control around the Chicago River's North Branch. In the process, the ecology of the Great Lakes and Mississippi basin became more interconnected than ever.

Figure 1
Chicago Area Waterway System



More major improvements for waterborne commerce came in 1922 with the opening of the 16-mile Cal Sag Channel, which forged a more southerly route between the CSSC and Lake Michigan. The O'Brien Lock, located several miles from the Illinois-Indiana boundary at the southeastern edge of Chicago, was built as part of these improvements and is situated where the Channel meets the Calumet River, an estuary of Lake Michigan. The overwhelming majority of commercial tonnage (presently more than 98%) shipped over the Illinois waterway system en route to the Great Lakes has used this lock for many decades

Like the older Chicago Lock, the O'Brien Lock and the Lockport Lock (a third lock facility in metropolitan Chicago that is further downstream) serve both navigational and flood-control functions. Today, these locks together with the region's navigable rivers and channels form the Chicago Area Waterway System, which stretches 78 miles. Like most of the other inland waterways in the United States serving commercial navigation, USACE maintains the CAWS.

There are several dozen companies regularly involved in barge movements or maintenance activity services on the CAWS. Vessels carrying approximately 30 million tons of cargo move through the system annually. This commerce predominately involves Chicago-area industries, but a small fraction of the total tonnage is "through traffic" that originates and

terminates outside the metropolitan area (this is primarily tonnage arriving from or destined for Milwaukee, Wisconsin). Barges entering the Great Lakes typically do not travel beyond southern Lake Michigan, leaving most Great Lakes shipping to deep-draft vessels.

As we illustrate below, other stakeholders in the lock closure discussion include commercial tours operators and sightseeing services, public agencies, recreational boaters, marinas, and real-estate developers. In addition, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) manages the sluice gates adjacent to the Chicago Locks and Wilmette Pumping Station, located approximately 15 miles north of downtown Chicago, to control the flow of water in and out of CAWS, thereby facilitating stormwater and flood control for the region.

III. Annual Expenditures on Boat and Barge Service

The approximate scale of economic activity directly tied to the two locks can be estimated by totaling expenditures by consumers as well as shippers and receivers on watercraft that pass through the locks or depend on their availability in other ways. These estimates include expenditures made for boat-related trips, services, and closely related activities that would be affected by the termination of lock operations.

The accounting of expenditures is a useful way to understand the direct and indirect impacts of money flowing through a regional economy. These estimates should not be interpreted as representative of the net economic *costs* associated with terminating operations at the two locks. For example, if commerce in one sector diminishes, some expenditures will likely be redirected to other sectors of the economy. Nevertheless, the estimates offer a perspective on the breadth of the market that would be affected by the unavailability of the locks.

Commercial Shipping. Industrial enterprises spend an estimated $101 million annually on barge transport services that involve shipments through the two locks examined in this study. Our calculation is based on self-reported industry estimates of the average shipping price ($13.50 per ton) and the three-year average of shipping volumes through the locks, which is 7,462,000 tons.[1] More than 98% of this commercial traffic involved use of the more southerly O'Brien Lock.[2]

Others shippers in the CAWS, whose shipments do not use either of these two locks, also have a stake in decisions made regarding the locks, albeit to a lesser extent. This is due to the potentially adverse effects that terminating operations could have on barge utilization, the potential changes in water levels on rivers and canals, and lost access to barge-related services on the Calumet River if the locks cease to be regularly opened. (For a more detailed discussion of this, see Section IV). A particularly large number of services used by barge companies, such as repair and maintenance facilities and barge-tow providers, are located upstream of the O'Brien Lock. This market generates estimated $309 million annually, making total yearly expenditures for all barge services around $412 million.[3]

Recreational Boating. An estimated 2,550 boats pass through the locks every spring and summer to gain access to boat slips and other mooring facilities on Lake Michigan, primarily harbors managed by the Chicago Park District; this represents 45% of the approximate 5,600 boats that moor in Lake Michigan harbors. Other boats are permanently moored or stored downstream from the locks but make regular or occasional trips to the lake. Of these, an estimated 500 are moored during the summer season in marinas that are downstream of the locks

and thus would be unable to reach the lake if lock operations are terminated. Finally, there are boats that access the CAWS system using boat ramps or private facilities. Based on the number of recreational boats reported as operating through the locks annually, and taking into account the number of "marina boats" mentioned above, we estimate that, as a rough approximation, these boats account for about 8,000 – 10,000 roundtrips annually. We use a 9,000 roundtrip estimate in the analysis below.[4]

Estimates of annual spending by owners of watercraft in Illinois can be found in published USACE data that report expenditures for various types of "marina boats" and "non-marina" boats in Illinois. For the purposes of this analysis, we assume the same mix of large and smaller boats reported in these data. We project annual spending by boats at CPD facilities and riverfront marinas is equivalent to the weighted "marina boat" average elsewhere in the state, or $13,700 per boat. This estimate is inclusive of ancillary consumer expenses on boat trips, such as restaurant meals and retail expenditures. It is likely that boats moored on Lake Michigan harbors are larger than those moored on inland rivers and lakes, making this a relatively conservative estimate. For boats not moored at marinas, which tend to be smaller, we use the non-marina figures of $6,435 per boat.

These estimates suggest that recreational boaters using the locks to gain access to the lake cumulatively spend approximately $58.9 million annually on trip-related or craft-related goods and services. (See the computation spreadsheet for more details about these expenses). The total does not include spending by recreational boaters who use the river system but do not use the locks, such as those using canoes and inflatable craft. Nor does it consider the potential revenue impact of recreational boaters who make long excursions between the Mississippi Basin and the Great Lakes.

Commercial Cruises and Tours. An estimated 760,100 passengers purchase tickets for sightseeing and tour boats that pass through the locks annually.[5] These passengers pay an average of $31.00 per trip. Industry representatives estimate that these customers spend $5 - $10 per trip in addition to their fare on food, drink, and other items. (We use the midpoint of $7.50, making total spending of $38.50, in the analysis below).[6] Not included in these estimates (unlike that for recreational boats) is off-boat spending, such as that on parking and restaurant meals. We provide a more detailed summary of this industry in Section IV.

For some consumers, the availability of river tours and excursions is a principal reason for planning a trip to Chicago. As such, tour-boat activity is directly responsible for spending on hotels, restaurants, parking, and other items. There has not been a detailed published study on the buying habits of the boat-riding sector. Nor does the Chicago Tourism Bureau publish data on the importance of tour boat services to tourism, although it does note that more than 30% of consumers consider sightseeing as their primary motive for visiting Chicago.

To estimate the extent of "out of water" revenues attributable to sightseeing and tour boats, we considered the percentage of passengers using these boat services who made reservations in advance. Industry representatives estimate that 33% of tourists/travel agencies reserve excursions in advance, often purchasing nonrefundable tickets, which suggests that an appreciable share consider the boat trip important enough to justify making a commitment prior to their arrival at the loading area.[7] As a conservative measure, we assume that only a small fraction of these passengers (30%) are making trips to Chicago on account of these services. This suggests that 76,100 consumers annually come to the city for this reason; this number is equal to about 10% of all customers who use boat tours through the locks, or about three tenths of one percent of all tourists from out of town.

For these customers, whose trips can be directly tied to river cruises, we assign a value for consumer expenditures equal to the average daily spending reported by the Chicago Tourism Bureau—$343 per person—rather than the lower $38.50 amount assigned to the other 90%. Of course, more data collection (involving survey research) is necessary to obtain a more precise estimate, but the analysis suggests the overall spending attributable to scenic cruises and boats tours is in the vicinity of $52.4 million annually.

Public Protection. The Chicago Police Department and the Chicago Fire Department, use the locks for their marine-based public services. We were unable to obtain estimates of annual spending, and have instead used as a proxy figures each provided that represent the labor costs associated with creating stand-alone river operations if lock operations were to be terminated (see discussion in the next section). This total, $5,500,000 annually, provides a sense of the scale of their river operations, and should be interpreted as a lower-bound estimate, as it does not include fuel, supplies, and other costs.

Cumulatively, these estimates indicate that direct impact of boat activity involving vessels using the locks is approximately $529 million annually (Table 1). Using standard multipliers for indirect and induced effects from this spending, we estimate the total impacts to be $1.3 billion. (See Note A for a discussion of the expenditure multipliers we applied.) These totals do not include most spending by land-based consumers, such as those on the Chicago Riverwalk, in marina restaurants, and those using other amenities situated on CAWS. Nor do they include spending by the U.S. Coast Guard, for which no information was available.

Table 1
Estimated Financial Impact of Vessels
Using the Chicago Lock and O'Brien Lock

Category	Annual Direct Spending	Multiplier for Induced and Indirect Effects	Cumulative Economic Impact
Commercial Shipping	$412,000,000	see Note A	$992,920,000
Recreational Boating	$58,885,000	" "	$141,912,850
Commercial Cruises and Tours	$52,409,895	" "	$126,305,437
Municipal Protection	$5,500,000	" "	$13,255,000
Total	$528,686,580	" "	$1,274,393,287

Note A: An expenditure multiplier of 1.41 is used to estimate the induced and indirect impacts. This number was determined to be representative based on previous studies on transportation and recreational activities involving Illinois industry using RIMS. This multiplier is also similar to those used in other studies of Great Lakes shipping and boating activity.

As is evident in Table 1, commercial shipping and recreational boating are the largest categories, followed by commercial cruises and tours. As previously noted, these figures should not be interpreted as indicative of the economic costs of terminating operations at the locks, which we estimate in Section III. Furthermore, the impacts of commercial shipping expenditures will be divided between metropolitan Chicago and other river ports served by the barge industry. A much more extensive analysis will be necessary to consider this issue in greater detail; this analysis should be recognized as providing only an approximation.

IV. Lost Value and Added Costs due to the Termination of Lock Operation

This section offers estimates of the lost economic value and cost escalation that would result from the termination of operations at the locks, the sluice gates, and the Wilmette Pumping Station. These estimates include reductions in consumer surplus, declines in the value of economic assets, and the additional financial burden imposed on government departments to provide the same level of service.

Consumer surplus is a measure of the value a consumer gains from engaging in an economic activity. It is the net benefit to the consumer and is calculated as the total value from consuming a good or service minus the expenditure on that good or service. Consumer surplus is therefore distinct from price, which measures the unit cost to the consumer and not the benefit. This notion is particularly important for measuring recreational activity, as it can be used to measure how the value of an outdoor recreational experience is affected by changes in price, accessibility to the outdoor resource, quality of the resource, distance to a recreation area, and other factors. If the activity itself is no longer available due to changes in environment or accessibility, the expenditure can be recovered and spent on something else while the consumer surplus is lost.

Table 2
Major Categories of Economic Costs Evaluated

1. *Changes in the cost of moving commodities due to the loss of two shipping lanes.*

This category reflects the effects of higher transportation costs associated with the movement of goods. These estimates should also account for changes in the utilization of barge equipment, as well as changes in the speed and reliability of service. They should also include the non-market (external) costs associated with various forms of transportation.

2. *Lost value resulting from the inability of recreational vessels, as well as commercial tour and cruise boats, to access the locks and the lake from the river system.*

This category of costs is indicative of the loss of value to pleasure boaters and consumers of fee-for-service operations that involve use of the locks.

3. *Costs imposed on the city as a result of the loss of public-utility functions using the river system, including flood prevention, stormwater management and emergency response.*

These costs include the value of the locks in reducing water levels related to storm mitigation and flood prevention in the Chicago River, and the need to increase expenditures by various city departments to maintain comparable police and fire services.

4. *The effects of lock closure on the value of the river as a conduit for real-estate development and as a cultural, recreational, and tourism amenity.*

This category includes the loss of economic benefit resulting from the potential fall in property values due to factors such as diminished water quality and aesthetic qualities of the river system, and lack of access to the lake.

Most of the losses in value or cost increases can be assigned to one of four categories described above in Table 2. The first category emphasizes transportation costs, while the final three categories encompass issues of aesthetics, water quality, and consumer preference. Each is evaluated in separate sections below.

a. Costs of Commodity Movement

Barge transportation has consistently been shown to be less expensive for industries on the inland waterway system than rail and truck transportation for the shipment of bulk commodities.[8] The cost difference per ton shipped tends to be less for bulky commodities (such as grain) than for denser ones (such as crushed rock) due to the relative advantages of water transport with respect to the heaviest loads. Nevertheless, the relationship between barge costs and that of other forms of transportation is dynamic. The availability of barges, for example, can be an incentive for railroads to keep their rates low.

Costs of lock closure for existing shippers. A Tennessee Valley Authority study using data from the late 1990s demonstrated that there were significant cost advantages to barge transportation. The Texas Transportation Institute (TTI), adjusting this estimate for inflation, reported that in 2005, the approximate difference was $11/ton. A University of Missouri study

concluded that the cost differences were $6.76 for asphalt projects, $13.05 for cement, $13.16 for fertilizer, and a lesser amount for agricultural commodities. This latter study examines shipping costs from points on the Missouri River, which is also part of the Mississippi River basin and thus has certain geographic similarities to the Illinois Waterway system.

The USACE estimated in its Interbasin Transfer Study, which is slated for completion in 2011, that closing the Chicago and O'Brien locks would cost shippers between $5 and $26 more per ton, depending on the type of commodity involved. This study is not yet complete, however, and the underlying methodology has not yet been formally disclosed. Therefore, we do not use these estimates in the analysis below.

For purposes of this study, we use a composite estimate that uses the midpoint between the TTI and Missouri estimates. (With regard to the Missouri estimate, we tabulated the average cost difference by considering the mix of agricultural and non-agricultural commodities shipping through the two locks.[9]) We then convert all figures into current (2010) dollars. According to this approach, the average cost increase will be roughly $11.96/ton.

An argument can be made that this figure is either too high or too low. As in each of the other studies, we made the simplifying assumption that demand is completely inelastic. Furthermore, the $11.96/ton estimate does not account for the higher cost of truck transportation in congested metropolitan areas. It does not fully account for the prevalence of tanker operations on CAWS, for which shifting to rail and truck transport is relatively difficult. The argument could also be made that Chicago's status as a highly competitive transportation hub would make switching to other modes less costly.

Regardless, this approach provides a reasonable, middle ground estimate. With 7,289,428 tons moving through the Chicago and O'Brien locks annually (this is a three year moving average for 2006 – 2008), the increase in costs for shippers is estimated at approximately $89 million.

Costs to other Barge Users in Illinois. Although terminating operation of the locks will principally affect customers who ship through the affected locks, it would affect other users on Illinois and Indiana waterway systems as well. Closure could also reduce the level of barge utilization, reduce the density of operations, and separate shippers from businesses operating barge tow and tugboat services as well as repair/maintenance services.

An important factor affecting barge utilization is the extent to which "upstream" and "downstream" traffic can be effectively balanced. At the O'Brien Lock, upstream traffic exceeds downstream traffic by a wide margin.[10] As you move south of the Lockport Lock, conversely, downstream traffic exceeds upstream traffic by an ever-widening margin. The growing imbalance is partially due to the rising volume of grain that is shipped to Mississippi River ports from downstate terminals.

Ending operations at the two locks would most directly affect upstream traffic, aggravating the traffic-imbalance problem. At present, barge companies often "cycle" their equipment through the CAWS system to minimize the costs of moving empties. For example, a company may transport a load from the Mississippi basin through the locks to a manufacturing facility in Gary, Indiana. That same barge might then return as an empty through the O'Brien Lock before picking up a load destined for a downstream destination.

The importance of the O'Brien Lock for such equipment positioning is exemplified by the number of empties that move through it annually. In 2007, 30% of all of its barge movements were empties, an appreciably higher percentage than most other locks on the state's waterway system.[11] If the movement of upstream barges (for reasons noted earlier) is reduced by 40% on account of the closing of the O'Brien Lock due to the diversion of tonnage to rail and truck transport, it is likely that at least 750 fewer empty barges would return to the CAWS for downstream shipments. Several hundred more barges may need to deadhead from New Orleans to customers shipping downstream.

To illustrate the potential this creates for cost escalation, consider the approximate cost of transporting 750 barges an additional 600 miles to support downstream movements.[12] Industry representatives put the transporting and opportunity costs of tying up an unloaded barge for a single day at roughly $750.[13] With barges traveling at roughly 6 m.p.h., and assuming an additional 600 miles of deadheading, each barge would be lost for slightly more than four days—at a total cost of about $3,125/barge. The total annual cost for decreased barge utilization and increased dead-heading cost for 750 barges would be roughly $2.3 million annually. Under a less favorable scenario, in which an appreciable percentage of barges would travel empty the entire 1,400-mile distance from New Orleans, the increased costs would be much greater.

This estimate does not include the costs imposed on downstream shippers resulting from their separation of barge-tow and repair facilities. Nor does it account for the losses that would be incurred by operators who have built specialized barge equipment that cannot be easily utilized elsewhere. A more extensive analysis will be necessary to approximate these costs.

Costs to Intra-Lake Michigan Barge Users. Several shippers rely on barges to move traffic between points on or near the southern part of Lake Michigan. This traffic does not directly use the locks but would be affected nonetheless. If the locks are no longer available, these operations would probably not be sustainable on a stand-alone basis. Moving the affected commodities on deep-draft vessels would be difficult or impossible in many instances, due to the associated terminal costs and the limited depth of the loading areas some of these barges serve.

Without barge traffic moving through the locks, the equipment used for these operations would likely not be effectively utilized, as these movements tend to fluctuate from week to week. It would likely be difficult to justify keeping barges upstream of the locks. Each autumn, barge operators would need to make a complicated equipment transfer to warmer water. This would entail towing barges through the Straits of Mackinac and Lake Erie, through the New York Barge Canal, and down the Intercoastal Waterways. This journey back to the Mississippi Basin is more than 750 miles longer than the present routing through the O'Brien Lock. A reverse trip would be necessary in the spring.

Accurate data on the size of this market is not available. Based on reported shipping patterns noted by industry representatives, a conservative estimate would be that this market encompassed 1 million annual tons (or about 1/7 of the tonnage moving through the O'Brien lock). Due to the short-haul nature of these movements, we assign a value of $5.98 ton—half of the $11.96 estimate used earlier—for the added transportation cost to this market due to the probable discontinuation of barge service. This results in a total additional cost of lock closure of $5.9 million. More research will be needed to develop more accurate measures of the costs as well as a precise estimate of tonnage.

External Costs and Highway Cost Responsibility. All transportation modes generate external costs in the form of pollution, congestion, and safety risks. For some modes, these are

not offset by user fees, creating inefficiency in the use of resources. To develop estimates on changes in these costs, we use widely accepted and frequently cited economic estimates by David Forkenbrock. Forkenbrock's research estimates the external costs to be 0.38 cents/ton for rail service and 1.13 cents/ton for motor carrier (truck) estimate.[14] This study does not measure the external costs of barge traffic. Other studies, however, have suggested the external costs for barge movements are much lower (see Bray, et. al, 1998). Since barge transport has been shown to be more than 33% more fuel efficient than rail service and subject to significantly less accident risk than these other modes, the external costs are almost certainly smaller per ton mile. However, to be conservative, we use a rate for barge transport equal to that of rail transportation.

Shifting traffic to heavy trucks also increases wear and tear on the highway system, most notably in the form of pavement and structural fatigue. Here, too, we use a widely accepted estimate by Forkenbrock, whose research estimates the uncompensated cost of road damage from heavy trucks at $0.31 per ton. Using the traffic figures described above, and estimates on the approximate modal split indicated on our computational spreadsheet, we estimate the additional costs to be $27.5 million annually.[15] (This estimate is based on a scenario of trains and trucks handling 30% and 35%, respectively, of the ton-miles currently moving by barge through the two locks.) This figure does not account for possible offsetting reductions on the cost of maintaining the waterway system as barge traffic declines.

b. Lost value to recreational boaters and consumers of commercial tours and cruises due to the closure of the locks

The implications of terminating operation of the locks differ widely between the various types of boats that use them. We consider separately the various types of recreational boats in the analysis below.

<u>Boats using Chicago Park District facilities and marinas on the Calumet River</u>. Between April and June each year, an estimated 2,600 recreational boats depart marinas, boat ramps, or winter storage facilities on the Chicago River or Cal Sag Channel en route to Chicago Park District (CPD) facilities on Lake Michigan, where they remain for the summer season. The "flotilla" is reversed each autumn, when boat owners return to the rivers for winter storage. Altogether, boats transiting the locks to reach harbors and marinas appear to account for slightly less than half (we use an estimate of 45 percent) of the roughly 5,600 boats using CPD harbors during summer.

The remaining 55% of boats moored on Chicago's harbors tend to be pulled from the water at lakeside boat ramps or brought to marinas or boat ramps in Indiana or southern Wisconsin. These boats do not travel through the locks to access the lake, and we assume they would be completely unaffected. As a general rule, however, boats that use the locks to reach winter storage locations tend to be larger than those that do not.

If the locks were no longer available, it is not clear how the owners of the 2,600 boats would access the lakefront. A small share, about 10%, could be transported to the lakefront on trailers; they are small, light, and narrow enough to be pulled by the owner's car or light truck.[16] The owners of many of these boats would likely drive to a lakefront ramp and face only relatively modest inconvenience. For these boaters, we assign a value of $145 (see Appendix A) for the inconvenience of losing their preferred logistical alternative at the beginning and end of the boating reason.[17] (We assume these boaters already have access to a trailer.)

The remaining 90% of boats would need to divert to distant marinas or storage areas, all of which are a considerable distance from CPD harbors. The owners of these estimated 2,360 boats would likely have difficulties finding marinas or boatyards able to provide winter storage. New capacity would need to be built.

Moreover, these boaters would incur additional monetary and nonmonetary costs, such as added transportation expense, boat wear-and-tear, and lost time. Fuel consumption varies widely by boat, but the overall average for most marina boats is around one mile per gallon. A roundtrip from Chicago to Kenosha, Wisconsin (a distance of 60 miles each way), consequently, would cost the average boater approximately $550 in fuel. Most owners make several trips (typically by car) to their boats to perform preparatory activities before launching their craft during the spring season. These trips would become more costly and time consuming. Considering how marinas are distributed across the southern end of Lake Michigan, our estimates suggest that affected boat owners would incur 18 or more additional hours of travel time per person per year as well as $720 in additional operating costs (boat and highway combined).

For purposes of this study, we use these estimates and the standard microeconomic assumption that travelers disvalue additional travel time at about one-half of their wage rate. We assume no additional costs for boat storage or necessary capital outlays (despite the apparent lack of existing capacity) beyond what these boaters already spend. We also assume that the added travel time would affect two people for each boat. This suggests additional costs for these vessel owners of $1,638 per boat.[18]

The lost value to boat users from losing their preferred option would, as a rough approximation, be about $5.1 million annually. (As a simplification, we assume that the demand for boat slips is inelastic with respect to cost of accessing the lake.)

Boaters Storing their Equipment Downstream of the Locks. An estimated 600 recreational boat owners use commercial boat slips at one of several marinas on the Chicago River or Cal Sag Channel. These boaters would be even more acutely affected by the lock closures. To understand their approximate economic losses, we reviewed the economic literature measuring value that consumers place on having access to a wide variety of water-related recreational amenities. This extensive body of work, summarized in the Appendix A, suggests an average loss of $47 - $87 per boat trip from the loss of a recreational alternative. We use the midpoint of this range, $67 per boat, in our analysis.

To develop an annual cost per boat, we applied the $67 estimate to USACE's estimates of the number of trips taken annually by boats moored in marinas. This suggests that closing the locks result in a $1,005 loss in value for each affected boat. This appears to be a lower bound, considering that, as previously noted, the total annual spending for marina boats is more than $13,000 annually.

Our analysis also considers the lost value for recreational boaters who do not operate out of marinas; instead, these boats launch their vessels through other means, such as by using public boat ramps or private boat slips. These boaters account for (as previously noted) an estimated 9,000 roundtrips to the lake annually. Altogether, using the above coefficient, this suggests that a cumulative estimate of the economic losses to recreational boaters is $5.1 million annually (See computational spreadsheet for details).

Commercial Tours and Cruises. Approximately 75% of all tour and cruise activity in Chicago that uses the river system involves use of the locks. A recent survey by the Passenger

Vessel Association elicited responses from five of the seven tour operators. This survey showed that the river-cruise industry has a total boat capacity for 4,500 to 5,100 passengers. The five companies responding to the survey employ 604 workers and have an approximately $7 million payroll. In 2009, their boats used the Chicago Lock 7,790 times.[19]

Accounting for the fact that several operators did not respond to the survey, we estimate that 760,000 paid customers pass through the locks each year. This represents about half of the total Chicago boat-cruise market, with the other half primarily operating off of Navy Pier. The Pier's operations tend to focus more heavily on dinner cruises and special-event outings, which are longer in duration and less educationally focused. These cruises generally do not use the locks.

Although tour operators could specialize in lake-only or river-only cruises as lock operations cease, the evidence suggests that the value of river-oriented operations would be diminished. The absence of through-boat activity, such as the passage of recreational boats and yachts, as well as a diminution of water quality, would likely hamper the appeal of river cruises. Moreover, the locks are a major tourist attraction themselves—many groups, for example, take cruises primarily to pass through them—and the separation of the lake and river system would hamper the utilization of boat equipment. Some boats primarily navigate the river by day and Lake Michigan by night, often in response to heavy demand for watching the sunset and fireworks (scheduled twice weekly) around Navy Pier. The nature of these markets suggest that most of the river market would be lost if tourists needed to travel via cab or bus to the pier for a different type of cruise.

For purpose of this analysis, we assume that the existing lake-only and river-only cruises would be completely unaffected—despite potential changes in water quality on the river system—while those using the locks would experience lost value roughly equivalent to the typical value observed in economic-valuation studies involving water-related excursion activities. These prior studies, which we summarize in Appendix A, suggest that people derive approximately $18 – 34 consumer surplus from expenditures on these activities For purposes of analysis, we use the midpoint value of $26 per trip. The cumulative effect of this lost value is $19.6 million/year.

c. Public Service, Public Protection and Stormwater

These costs can be divided into two categories: public protection and flood control.

<u>Public protection: Police and Fire</u>. The Chicago Police Department and Chicago Fire Department both maintain facilities designed to jointly support operations on the lake and river system. The Chicago Fire Department's Air Sea Rescue Division facility, located near the mouth of the Chicago River on Lake Michigan, is equipped with two fireboats, one 96-foot boat and one 33-foot boat. This facility allows the Department to respond to emergency locations on the inland Waterway System in 15 to 40 minutes and more quickly to those on the lake.

The Fire Department considers maintaining a marine presence on both sides of the locks to be essential to its mission. If lock operations cease, this would require adding a fireboat and personnel at a new location on the Chicago River. The CFD estimates that adding additional 33-foot and 96-foot vessels would cost $350,000 and $2.76 million, respectively, and that added personnel would cost another $2.75 million annually. The department would also need to make capital investments to handle these boats and the associated personnel.[20]

The Chicago Police Department's Marine & Helicopter Unit uses eight watercraft for search, rescue, and recovery operations as well as for law enforcement and homeland security patrols and inspections. These boats, housed on the South Branch of the Chicago River, are frequently users of the locks. In 2009, the boats used the locks, on average, several times daily and made 7,314 site inspections. If lock operations cease, the department would need to purchase an ice-breaking watercraft at a cost of approximately $1 million and to budget for the addition of between 16 and 24 personnel, at a cost of between $1.8 million and $2.7 million annually. (We use $2.3 million, which is near the midpoint of this range, in our analysis). Although appreciable capital costs to prepare facilities for the changes would also be incurred, there is uncertainty about their magnitude, so we assigned only a nominal value for these costs of $150,000 each to both the CPD and CFD. The actual costs will likely be much higher.

We amortize the costs of the boats and facilities over an eight-year period, which suggests the total costs would be approximately $5.7 million annually over this initial period and $5.1 million thereafter. This is a lower-count estimate as it does not include the cost of additional fuel, supplies, and other necessary expenditures.

Stormwater, Flooding and Water Reclamation. Stormwater management and flooding has been a problem in metropolitan Chicago for more than a century. Due to the flat topography and the limited capacity of existing waterways to handle runoff, heavy emphasis has been placed on reducing the costs of flooded basements, flash floods, and the pollution attributable to excessive water runoff. A great deal of investment has been made to modify the river system to alleviate these problems. The decision to reverse the flow of the Chicago River and build the CSSC, for example, was motivated by these concerns. Moreover, the locks must be periodically opened to allow rising waters of the river to flow into the lake to compensate for the inadequacy of stormwater systems.

The efforts to control flooding crossed an important milestone in the late 1980s when the Metropolitan Water Reclamation District of Greater Chicago (MWRD) completed extensive portions of its Tunnel and Reservoir Plan (TARP). This system of tunnels and reservoirs, popularly called the "Deep Tunnel Project", channels stormwater over a 375 square-mile area into reservoirs so that it can be gradually discharged in the river system. MWRD has spent about $3 billion on this initiative, and recent estimates suggest these improvements are providing $41 million in annual benefits. The first of the two construction stages is slated for completion in 2014.[21] For a variety of reasons, including funding concerns, however, the construction timetable will likely drag on more than 40 years longer than anticipated, and the second phase is not slated for completion until 2023.

The principal constraint on the system remains the limited capacity of the waterway system between Sag Junction to Lockport, which is capable of handling only 20,000 cubic feet of water per second, which is grossly insufficient after heavy rain. As the region's development footprint expands, consequently, the TARP system is strained. Basement flooding from sewer backup remains a problem, and has been estimated by USACE to cost $150 million annually.[22]

MWRD has reported to the Rapid Response Work Group that it would be necessary to bore a tunnel between the North Branch of the river from the facility at Foster Avenue to the McCook Reservoir, a distance of more than 10 miles, if operations at the locks, sluice gates, and pump station are halted. This proposed tunnel, which would provide protection for 1.2 million structures, was part of the original TARP package; construction, however, was cancelled when it was deemed unnecessary for controlling flooding. Other investments would also likely be

necessary due to the termination of operations at the O'Brien Lock, including expansion of the McCook Reservoir to provide protection to 182,000 structures.

Our assessment suggests that MWRD's estimate that it would cost approximately $2.5 billion to build the tunnel (the equivalent of about $1,500 per household served) to be credible. Another $56 million would be needed to support improvements to the Little Calumet River. These improvements (which are in addition to the estimated $726 million needed to finish the second phase of TARP) would require a lengthy construction timetable after planning and design. Although the expected costs of flood damage without the improvements aren't presently known, testimony by Dr. Yu-Chun Su suggests the costs could exceed $1 billion annually.[23]

For purposes of this study, we estimate the amortized cost of making these improvements deemed necessary by MWRD over an eight year construction period and assume no additional costs beyond that period. This suggests (with an allowance for 4% annual cost escalation) that the costs would be $375 million/year over these eight years. Heavy investments could likely be necessary even if allowances were made to open the locks only during moments of rare flooding. The routine opening of locks serves to lower water levels on the Chicago River and Cal-Sag Channels after periods of heavy precipitation. Although our cost estimates are speculative (construction could not likely begin for several years) amortizing the costs over eight years illustrates the extent of the funding commitment that would be necessary to see the project through to completion.

d. Value of Property Along the River System and Other Issues Related to Proximity

There has been extensive analysis in recent years about the economic value of a "healthy" river system to the Chicago economy. Little of it, however, has been formally published in peer-reviewed journals. A report commissioned by local nonprofit organizations postulates that the vitality of the river system has resulted in property value increases of more than $400 million in the early 2000s. It notes that the river's value as a recreational amenity has risen due to regulatory changes made in the 1980s that dramatically improved water quality. It also notes that there is data suggesting water quality has improved as a result.[24]

This body of work also notes that effluent from reclamation plants operated by MWRD currently makes up about 30% of the Chicago River's annual flow—a percentage that would likely rise significantly if Lake Michigan water no longer passed through opened locks. Water from the lake tends to be cleaner than effluent from MWRD, suggesting that there would be a material reduction in water quality if the locks were closed.

Based on the Supreme Court testimony by Kevin Boyle of Virginia Polytechnic University, the loss of discretionary water diversion from Lake Michigan into the CAWS may lead to noxious conditions and fish kills which can only be partially overcome via existing alternative measures in the short term. Further, in his testimony, Colonel Vincent V. Quarles states that the lack of lake flows could lead to low water levels and stagnant conditions potentially affecting CAWS users.

The City of Chicago, after tabulating the Equalized Assessed Value (EAV) of property along the river system, postulated that property values rose by more than $400 million due to the river's expanding role as a recreational and aesthetic amenity during the early 2000s. Nevertheless, this study did not control for exogenous factors, such as the proximity of many of the studied properties to the central business district. Recent expansion of residential housing along the Chicago River, however, lends credence to the view that the inland waterways have

been an important factor in real-estate development, particularly in the Central Area and along the North Branch. In addition to the established marinas such as Marina City and River City, several new ones on more outlying river segments, including the Chinatown Area, as well as the Trump Tower, Lake Shore East, and new condominium towers provide support for the notion that property along the river increasingly sells at a premium.

The city has invested approximately $22 million and leveraged additional private investment for the Chicago Riverwalk, which extends from Lake Shore Drive to Franklin Street. This system of public walkways and seating areas along the water's edge is designed to showcase the "canyon of skyscrapers" while watching the boats go by. The Riverwalk presently has six cafes and is a jumping off point for boat cruises, water taxis, bike rentals and tours. The McCormick Tribune Bridgehouse and Chicago River Museum on Michigan Avenue also are illustrative of the river's role in tourism.

Many industrial properties along the river and canal system, however, do not appear to have benefitted from this effect. The demand for industrial property along the river system remains relatively weak, in part due to the economic downtown and the county's tax structure. Moreover, recreational activity that involves direct contact with the river, such as swimming and tubing, remains quite limited, partially due to variability in the level of water quality.

An informed estimate of the decline in property value that would occur as a result of the lock closures can be made by reviewing several different methodological approaches. Boyle's research indicates that even relatively modest *improvements* in water quality could generate $1.05 billion in value for the region in the form of improved health, recreation, and tourism opportunities. This equates to a benefit of about $47 per resident of the city. A Friends of the Chicago River report suggests that improved water quality could generate more than $500 million in new economic activity over 20 year period, primarily in the form of increased recreation. The Brookings Institution maintains that improved water quality could increase property values in the Great Lakes by 1% to 2% percent in densely populated urban areas and a greater amount in other areas. (See the reference section for full citations on these studies.)

Economic analysis exploring changes in property values in other regions that are the result of changes in the quality of waterways are also useful to consider. As we note in Appendix B, there is a particularly extensive literature on the elasticity of property values with respect to water quality (as measured by the percent change in contaminants in the water). Using an estimate near the median of the elasticity estimates made in these studies (.05), and assuming a hypothetical 10% reduction in water quality, we estimate that property values would fall by 0.5%.

Data from the City of Chicago indicates that the market value of property within an 800-foot buffer of the river system was $10.22 billion in 2006. This suggests a decline in property value of $51 million dollars. This estimate should be recognized as being speculative, but it is also conservative, as it does not account for the effects that lost access to the lake and the diminishment of the other qualities of the river system (such as a decline in the recreational value and tourism role of the system) would likely have on property values. The decline in value is less than half the effect suggested by Austin, et.al, in the Brookings Institution study (2007) and only a small fraction of the estimate made by Sulski of the benefits of improved water quality. The costs to property owners could take the form of smaller increases in land value. Regardless, more research in this area is clearly needed.

V. Conclusions

The findings of this study about the implications of terminating operations at the lock facilities and the Wilmette Pumping Station suggest that the decision should not be made lightly. A summary of the economic losses from the termination of lock operations appears in Table 3.

Table 3

Summary of Economic Loss from Termination of Lock Operations

	Year 1	Years 2 - 8	Years 9 - 20
Commercial Shipping	$95,230,082	$95,230,082	$95,230,082
External & Highway Costs	$29,828,326	$29,828,326	$29,828,326
Recreational boating	$5,077,920	$5,077,920	$5,077,920
River Cruises and Tours	$19,762,600	$19,762,600	$19,762,600
Flood prevention	$375,478,436	$375,478,436	
Municipal protection	$5,643,913	$5,643,913	$5,050,000
Property value loss	$51,000,000		
Total	$582,021,277	$531,021,277	$154,948,928

The economic value lost from permanent closure is estimated (as a lower bound estimate) to be $582 million the first year, $531 annually over the subsequent seven years, and $153 million annually thereafter. The net present value of these costs, over a 20-year planning horizon at a four percent discount rate, is $4.7 billion.

Additional research is needed for policymakers to understand the full effects of this policy alternative. The decision-making process could benefit from a careful consideration of other economic issues not included in this study, such as the investments that industries have made in specialized equipment and facilities, the effects of changing shipping patterns on employment at suppliers of barge services, and the effects that changes in barge transportation will have on the rates charged by competing transportation modes. Furthermore, the analysis should be expanded to consider changes in tax revenue and the effects of changing water quality on the demand for river-oriented recreation, such as paddling trips and fishing.

There is a particular need for more research on the value of recreational boating and tour-boat operations on urban waterways. Survey data could help reveal how local consumers make decisions regarding tour boat trips relative to other local activities, as well as how tour boat trips contribute to Chicago tourism from out-of-town visitors. This data could then be used to assess how various trip characteristics, such as lock passage, views and river water quality affect the overall economic value of the boat trips. Such a study could utilize some of the same techniques that researchers at the University of Chicago and RCF Economic and Financial Consulting used to measure the value of area beaches.

The computation spreadsheet prepared as part of this study allows for evaluation of different scenarios and testing different assumptions. This provides a tool that can be used to deal with some of the uncertainty about the long-range effects of lock closure.

VI. Appendix

A. Methods to Value Recreational Boating

The most common method used to measure the economic value associated with water-based recreation is the travel cost model. It is based on the travel costs and travel time required to engage in a recreational activity, while accounting for the next best use of an individual's time and the other available recreational alternatives. Since this methods is survey based, it is often time and labor intensive to employ, and a commonly-utilized alternative to measuring recreation value relies on a case-specific and well-informed transfer of benefits from existing travel cost literature.

Numerous studies have provided estimates on the value of a recreational boating day either through primary valuation or through a benefit transfer or meta-analysis of existing estimates. Estimates of the consumer surplus of recreational boating are fairly consistent across locations and range from $47 to $87 per boat trip in 2009 dollars[25]. We used the midpoint ($67/day) in our analysis. Other estimates of water-related recreation include the value of a day at the beach, which are also consistent across locations and range from $34-$44 in 2009 dollars.[26]

No estimates of the consumer surplus of a tour boat trip were found through an extensive literature search. While limited literature exists for luxury cruises, this is distinct from an urban boat tour which only lasts a couple of hours at most. In this case, the consumer surplus of a tour boat cruise is assumed to be proportion of the value of a recreational boat trip, based on the relative time difference of the trip. Wendella Boat Tours in Chicago offers three different tours ranging in length from 75 minutes to 2 hours and averaging 95 minutes in length. Assuming a recreational boating trip lasts an average of 4 hours, the average consumer surplus per hour is approximately $11.75 to $21.75[27]. The implied consumer surplus per 95 minute tour boat excursion is then approximately $18 - $34. For purposes of analysis, we use the midpoint of $26 per affected consumer.

B. Changes in Water Quality

Methods to Value Changes in Water Quality

A commonly-used approach to measuring the economic value associated with changes in water quality is the hedonic property method, which observes the impact of changes in water quality on the value of properties near the water body. This approach has been used extensively for measuring the economic value of various types of environmental quality changes. An alternative approach relies less on market prices and instead directly engages individuals to state their willingness to pay for environmental quality improvements. This technique called the contingent valuation method relies on surveys and interviews to simulate a referendum vote, although in a hypothetical setting. Again, because primary valuation is costly and time-intensive, the transfer of benefit estimates using these methods from the existing literature are a commonly applied technique.

Changes in Property Value Associated with Water Quality

Numerous studies have observed the changes in water-proximate property given changes in water quality from fecal coliform, pollutants from run off and water clarity. The range of imputed home price elasticities from the economic literature using the property value approach is -0.0002 to -0.07 for water quality degradation and +0.04 for an improvement in water clarity[28].

In 2006, the estimated market value of properties within 800 feet of the Chicago River was $10.22 billion. Using the range of -0.0002 to -0.07 for a 1% degradation in water quality, we use an elasticity of -0.05.

Willingness to Pay for Water Quality Changes

A common metric for measuring the willingness to pay for recreational water quality is a water quality ladder (WQL) scale which ranks recreational designation from 1 to 10, where 2.5 is "boatable", 5.1 is "fishable" and 7.0 is "swimmable"[29]. In a seminal study on the Clean Water Act, Carson and Mitchell estimated the mean household willingness to pay to improve water from "Non-boatable" to "Boatable" to range from $106 - $141 in 1983 dollars.

In testimony before the Illinois Pollution Control Board, Kevin Boyle reported an estimate of the willingness to pay for Cook County residents for an improvement in the CAWS water-quality index from 6.1 to 6.8 on the 10-point scale[30]. Using results of a meta-analysis of 18 water quality studies by Van Houtven, et al, he estimated the willingness to pay for the water quality improvement to be $47 per household per year in Cook County for a present value of $1.05 billion over 20 years for the improvement in water quality.

In a 1986 survey about Chicago waterways, Croke, et al. determine the mean household willingness to pay in Cook County for improved water quality to range from $33-$46. The range of willingness to pay is for varying levels of water quality in the Chicago waterways from improving water for outings ($33.49), outings and boating ($37.76) and outings, boating and fishing ($46.05).

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ENDNOTES

[1] No published information is available on the average cost of barge shipments per ton or ton-miles. This is a consensus based estimate provided by several shippers who do business in metropolitan Chicago.
[2] Based on average tonnage between 2006 and 2008 reported by the U.S. Army Corps of Engineers Data Navigation Center.
[3] Included in this estimate are expenditures on Intra-Great Lake operation. See Section III for details.
[4] This estimate was made in part by looking the approximate distribution of recreational boat trips in other previously mentioned categories and then determining how many more were taken so that the total is consistent with USACE estimates. These estimates suggest that the two locks serve slightly more than 40,000 recreational-vessel movements per year .
[5] This estimate was determined by using the estimate provided in Passenger Vessel Association survey and account for non-responses, which was conservatively assumed to be 10% of the total.
[6] Information on ticket prices and ancillary spending was provided by the Wendella Boat Company.
[7] Information on advance bookings was provided by the Wendella Boat Company.
[8] See especially studies by Texas Transportation Institute (2007) and University of Missouri (2004), listed in the reference section, to a discussion of differential costs of various modes of transportation.
[9] The estimate from the Missouri study is based on the follow assumed mix of barge commodities: 7% agricultural (based on USACE data for the two locks being studied) and the remaining 93% split equally between cement, asphalt, and fertilizer.
[10] Based on lock usage data from USACE Data Navigation Center.
[11] See computational spreadsheet on the Chaddick Institute web site for a summary of this calculation
[12] The estimate of 450 miles is based on a mix of shipments from various Mississippi River ports.
[13] This estimate is used by a major barge service provider about the opportunity cost of tying up a barge. It should be recognized as an approximation.
[14] David Forkenbrock (2001)
[15] This assumes a 800 mile average trip distance. See computational spreadsheet.

[16] These estimates are based on estimates made with assistance with area boat specialists, including Grant Crowley and other individuals affiliated with the Friends of the Chicago River.
[17] This estimate is based on the economic value recreational boats placed on proximity to water amenities in previous research. Boaters are affected twice annually by the loss of their preferred alternative ($72.50 per trip, once to launch their boat in spring and again to remove it in late summer or autumn).
[18] This is based on a wage rate among owners of marina boats of $40/hr. This likely understates the actual hourly earnings of the affected population.
[19] See the U.S. Army Corps of Engineers 2008 study, "*Great Lakes Recreational Boating"*.
[20] See testimony by Michael W. Fox, Chicago Police Department, and Steve E. Georgas, Chicago Fire Department. Citations provided in reference section.
[21] Information about capital costs provided to the author by MDRD in March 2010..
[22] See "Strategies for a Cleaner, Healthier, More Vibrant Chicago River," Friends of the Chicago River (2006).
[23] For reference to the Charles Quarles testimony, see reference list,
[24] Citation from Strategies document, 5.
[25] See Hushak and Bielen (2000), Wiggin, et al. (2009), Walsh, et al. (1992), Rosenberger and Loomis (2000).
[26] See Sohngen, et al. (1998), Shaikh (2006), Lew and Larson (2005).
[27] Consumer surplus may not necessarily be determined on an hourly basis and the marginal consumer surplus will likely be decreasing per hour. Given the limited information on the consumer surplus for boat tours, an average hourly consumer surplus is assumed to be the most appropriate method of calculation.
[28] See Poor, Pessango and Paul (2007), Leggett and Bockstael (2000), Ara, et al (2006)
[29] The Water Quality Ladder (WQL) was developed by Resources for the Future in 1986 and has been used by many researchers to assess recreational users' willingness to pay for steps up the WQL. See van Houtven, et al (2007) and Carson and Mitchell (1993) for more information on the WQL.
[30] Boyle's testimony before the Illinois Pollution Control Board focused on the economic benefits from improved CAWS water quality from recreation use designations by the Illinois EPA, which would be achieved with the implementation of additional wastewater disinfection.

A MODAL COMPARISON OF DOMESTIC FREIGHT TRANSPORTATION EFFECTS ON THE GENERAL PUBLIC

December 2007
Amended March 2009

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U.S. DEPARTMENT OF TRANSPORTATION
MARITIME ADMINISTRATION

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and

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FINAL REPORT

Prepared for
U.S. Maritime Administration
and
National Waterways Foundation

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DISCLAIMER

This research was performed in cooperation with the U.S. Maritime Administration (MARAD) and the National Waterways Foundation (NWF). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of MARAD or NWF. This report does not constitute a standard, specification, or regulation.

This document was modified in March 2009 to include information on Greenhouse Gas (GHG) emissions. The modifications are included in Chapter 4.

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CHAPTER 1: BACKGROUND AND SIGNIFICANCE

The Inland Waterway System (IWWS) is a key element in the nation's transportation system. The IWWS includes approximately 12,000 miles of navigable waterways and 240 lock sites that incorporate 275 lock chambers. It handles shipments to/from 38 states each year. The system is part of a larger system referred to as "America's Marine Highways" which encompasses both deep draft and shallow draft shipping.

In 2005, inland waterways maintained by the U.S. Army Corps of Engineers (Corps) handled over 624 million tons of freight (274 billion ton-miles)[1] valued at over $70 billion,[2] resulting in an average transportation cost savings of $11/ton (as compared to other modes).[3] This translates into more than $7 billion annually in transportation savings to America's economy. In 2003, barges moved 14% of intercity freight ton-miles for 3% of the freight bill.[4] Virtually all American consumers benefit from these lower transportation costs.

Thirty-one states are served by the Mississippi River System and the Gulf Intracoastal Waterway. States on the Gulf Coast and throughout the Midwest and Ohio Valley especially depend on the inland and intracoastal waterways. Texas and Louisiana each ship over $10 billion worth of cargo annually, while Illinois, Pennsylvania, West Virginia, Kentucky, Mississippi, and Alabama, each ship between $2 billion and $10 billion annually.[5] Over 60% of the nation's grain exports move by barge.[6] The Inland Waterway System is the primary artery for more than half of the nation's grain and oilseed exports, for about 20% of the coal for utility plants, and for about 22% of domestic petroleum movements.[7] Figure 1 shows the level to which the various states use the waterway system.

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[1] The U.S. Waterway System — Transportation Facts, Navigation Data Center, U.S. Army Corps of Engineers, February 2007.
[2] "Value to the Nation: Navigation", website maintained by U.S. Army Corps of Engineers, accessible at http://www.corpsresults.us/navigation/naveconomic.htm as of August 2007.
[3] Based on data produced by the Tennessee Valley Authority using 2001 statistics.
[4] "Transportation in America", 20th Edition, ENO Foundation, 2007.
[5] "Inland Waterway Navigation: Value to the Nation", brochure by U.S. Army Corps of Engineers, Institute for Water Resources, May 2000, accessible at http://www.iwr.usace.army.mil/docs/InlandNavigation.pdf as of September 2007.
[6] "A Reliable Waterway System Is Important to Agriculture", United States Department of Agriculture, Agricultural Marketing Service, August 2007, accessible at http://www.ams.usda.gov/tmd/TSB/WaterwaysFacts08-07.pdf as of September 2007.
[7] "The Declining Reliability of the U.S. Inland Waterway System", David V. Grier, U.S. Army Corps of Engineers, Institute for Water Resources, presented at 7th Marine Transportation System Research & Technology Coordination Conference, November 16-17, 2004, accessible at http://trb.org/Conferences/MTS/4A%20GrierPaper.pdf as of August 2007.

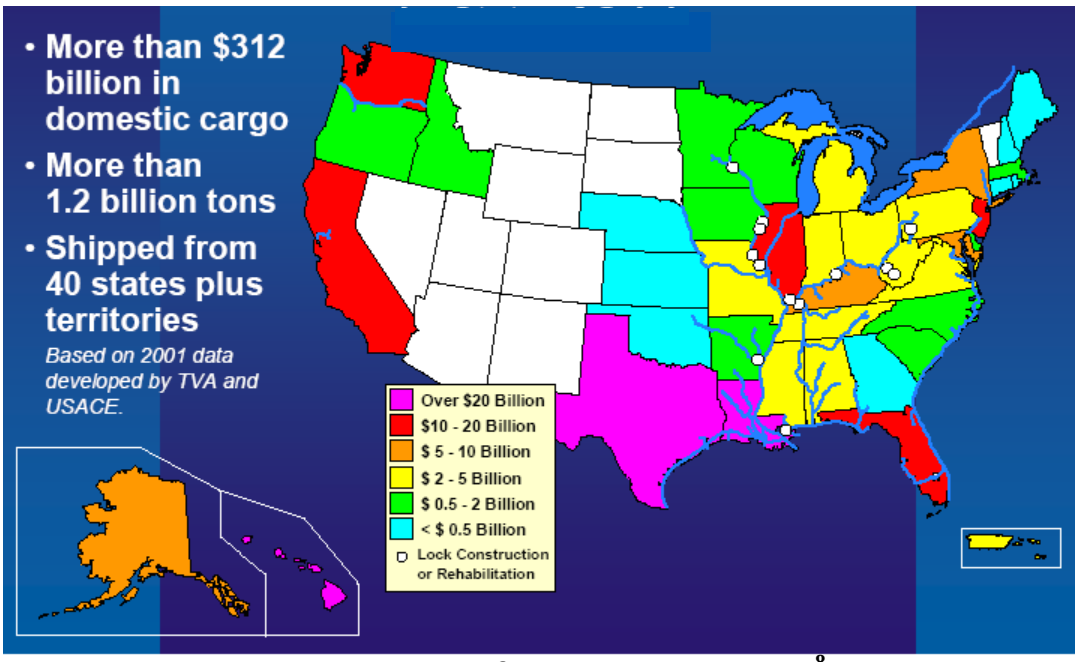

Figure 1. Value of IWW Cargo by State. [8]
Source: U.S. Army Corps of Engineers, Institute for Water Resources.

A wide variety of public, semi-public, and private entities is involved in the maintenance and operation of the waterway. The following list illustrates the types of enterprises that directly depend on the waterways:

- Ports
- Ocean-going ships
- Towboats and barges
- Ship-handling tugs
- Marine terminals
- Shipyards
- Offshore supply companies
- Brokers and agents
- Consultants, maritime attorneys
- Cruise services
- Suppliers and others

The federal agencies most directly involved with the inland waterways are the U.S. Department of Transportation, the Corps, and the U.S. Coast Guard.

The Inland Waterway System is one modal network within the entire pool of domestic transportation systems networks that include truck and rail modal networks. The entire surface transportation system is becoming increasingly congested. The ability to expand this system in a

[8] This figure was produced by David V. Grier, U.S. Army Corps of Engineers, Institute for Water Resources.

timely fashion is constrained by both funding and environmental issues. Many proponents of the inland waterway system point out that it provides an effective and efficient means of expanding capacity with less funding, has virtually unlimited capacity, and impacts the environment much less than the other modes of transportation.

Initially, this study was designed to focus on certain segments of the IWWS. However, for certain types of analyses, it is not feasible to segregate components of the system, i.e., river segments, rail segments, etc. In these cases, the analysis is performed on a system-wide level and includes the entire system. When it is desirable or necessary to focus on only certain segments, this study focuses primarily on the Mississippi River Basin, Ohio River Basin, the Gulf Intracoastal Waterway, and the Columbia/Snake River System. These segments limit the number of data sets that must be analyzed, but include a high percentage of the total cargo traffic and represent a diversity of waterway segment types. The level of analysis is noted in the body of the report, as appropriate. Figure 2 illustrates the dominance of these waterways in terms of the national tonnage totals for internal domestic freight movements.

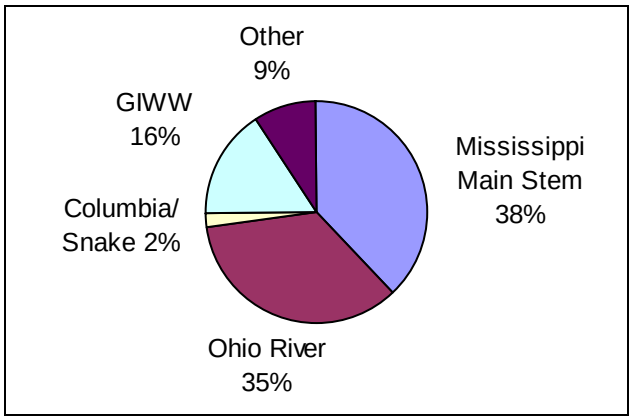

Figure 2. Composition of Internal Tonnage by Waterway.
Source: Waterborne Commerce of the United States, Calendar Year 2005, Part 5–National Summaries, U.S. Army Corps of Engineers

The Mississippi River System stretches from Minneapolis, Minnesota to New Orleans, Louisiana. The Illinois, Missouri, and Ohio River systems all empty into the Mississippi. Further south, the Arkansas and Ouachita Rivers also flow into the Mississippi. The Mississippi main stem runs for 1,800 miles; the entire system is 9,000 miles[9]. Approximately 513 million tons of domestic and coastwise freight were shipped on this system in 2005.[10]

The Ohio River System contains 2,800 miles of navigable waterways, flowing from Pittsburgh, Pennsylvania to Cairo, Illinois. This system--which encompasses seven other rivers that flow through nine states--is part of the larger Mississippi River system. Approximately 2/3 of the traffic on the Ohio River System originates and terminates on the system.

[9] U.S. Army Corps of Engineers, Institute for Water Resources. An Overview of the U.S. Inland Waterway System. IWR Report 05-NETS-R-12, November 1, 2005.
[10] Source: Waterborne Commerce of the United States, Calendar Year 2005, Part 5–National Summaries, accessible at http://www.iwr.usace.army.mil/ndc/wcsc/pdf/wcusnatl05.pdf as of August 2007.

The Gulf Intracoastal Waterway (GIWW) consists of 1,109 miles of navigable waterway along the Gulf Coast. The GIWW is part of a larger waterway system (1,992 miles) that includes various small rivers, bayous, and channels. In 2005, approximately 116 million tons of freight was shipped on the GIWW[11].

The Columbia/Snake River System includes 596 navigable miles of waterway. It is not connected to any other waterway system; instead it flows directly into the Pacific Ocean. Approximately 18 million tons of freight moved on this system in 2005.

Figure 3 shows the composition of 2005 domestic freight tonnage by principal commodity groups. This figure illustrates that a very high percentage of domestic freight traffic is composed of bulk commodities—commodities that are low in value per ton and very sensitive to freight rates.

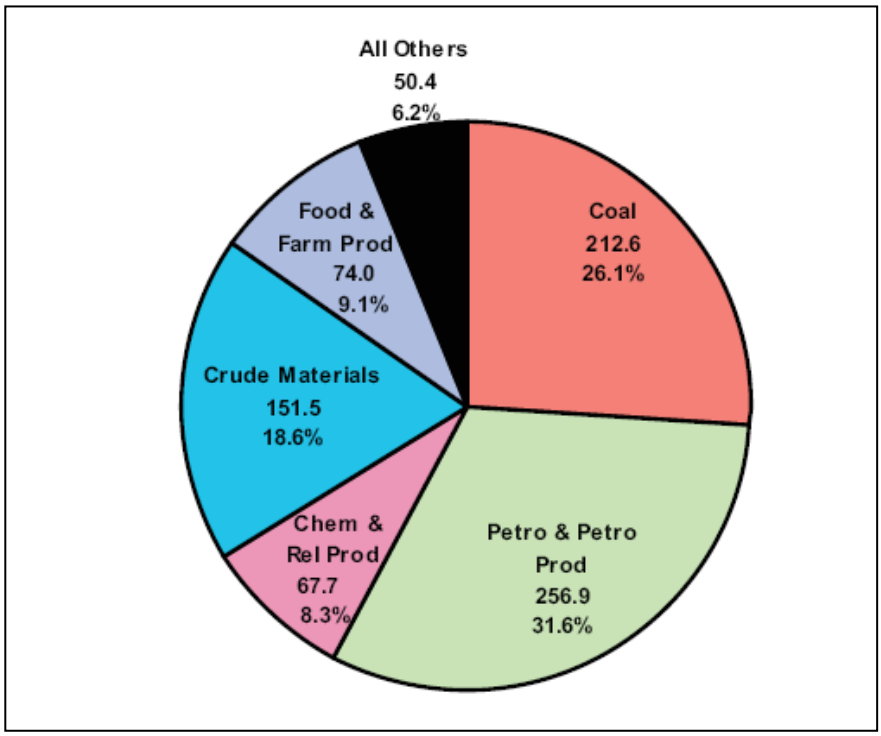

Figure 3. 2005 Barge Traffic by Commodity Group (in millions of tons).
Source: Waterborne Commerce of the United States, Calendar Year 2005, Part 5–National Summaries, U.S. Army Corps of Engineers

The economics of barge transportation are easily understood and well documented. This report updates and quantifies the *environmental*, selected *societal*, and *safety* impacts of utilizing barge transportation and compares these impacts to highway and rail transportation.

[11] Source: Waterborne Commerce of the United States, Calendar Year 2005, Part 5-National Summaries, accessible at http://www.iwr.usace.army.mil/ndc/wcsc/pdf/wcusnatl05.pdf as of August 2007.

In 1994, the Maritime Administration released a document titled "Environmental Advantages of Inland Barge Transportation." Using the best available data at the time, the document laid out the benefits of barge transportation compared to other modes with an emphasis on the following areas:

- Energy efficiency
- Safety
- Congestion
- Air/noise pollution
- Land use/social impacts
- Environmental aspects

Since that study, technology has advanced, operating conditions have changed, and new and updated data are available. This report examines many of the same aspects as the 1994 report, but using more current data, and—in some cases—new data sources.

Based on available data sources and existing research documents, these topical study areas were identified for this research:

- Cargo capacity
- Congestion
- Emissions
- Energy efficiency
- Safety impacts
- Infrastructure impacts

These topics are very similar to the topics covered in the 1994 MARAD report. They were selected because:

- They are issues associated with all modes, enabling their comparison across modes.
- Data availability allows the conduct of a scientifically sound and defensible analysis.
- The importance of these issues has been verified by industry contacts.
- They can be summarized and presented in ways the general public can understand.

IMPORTANT ASSUMPTIONS AND CONSTRAINTS

The hypothetical nature of this comparative study requires certain assumptions in order to enable valid comparisons across the modes.

The analysis is predicated on the assumption that cargo will be diverted to rail or highway (truck) modes in the event of a major waterway closure. The location of the closure and the alternative rail and highway routes available for bypass will determine any predominance in modal share. The geographical extent of the waterway system network does not allow for any realistic predictions to be made in regards to a closure location, the alternate modal routes available for bypass, or the modal split. As a result, this analysis adopts the all-or-nothing modal assignment principle. The analysis considered the possible impacts resulting from either a theoretical diversion of 100% of the current waterborne cargo to the highway mode OR a theoretical diversion of 100% of the current waterborne cargo to the rail mode.

This report presents a snapshot in time in order to focus on several vital issues. Analysis of the broad spectrum of economic consequences that could potentially result from any deviation from existing conditions is beyond the scope of this study. The data utilized in this research are publicly available and can be independently verified and utilized to support various analyses.

This analysis uses values of ton-miles of freight as the "common denominator" to enable a cross-modal comparison that takes into account both the shipment weight as well as the shipping distance. However, water and rail ton-mile data are available through 2005, whereas truck ton-miles are only available through 2004; therefore, data for 2001-2004 are used to provide a common time frame for comparison of ton-miles. Four sources were used for ton-mile data: *National Transportation Statistics - 2006, Table 1-46a: U.S. Ton-Miles of Freight (Millions); National Transportation Statistics - 2006, Table 1-46b, Special Tabulation (highway data); Association of American Railroads Website (2005 ton-miles); Waterborne Commerce Statistics - 2005.*

Most of the issues related to a theoretical waterborne freight diversion are examined on a national or system-wide level. The level of detail of the available data does not permit any disaggregation, for example, to the state level. In addition, a microscopic examination of individual pairs of origins and destinations of waterborne trips is beyond the objectives of this research project. The system-wide level of analysis cannot support reasonable traffic assignment on specific highway links. It only permits a reasonable allocation of the truck traffic that would replace waterborne freight transportation to the highest class of long haul roadway, the rural segments of the interstate system.

Detailed data for train fuel consumption or composition are generally proprietary, hence not publicly available. Therefore, the research team developed methodologies for cross-referencing available train data with compiled statistics in order to support the comparative analysis among modes.

Barge transportation is characterized by the longest haul operations, followed by rail, then by truck. This study is macroscopic in nature and focuses on the main stems of the major river systems. Considerable effort took place to investigate for possible differences in route lengths ("circuity") among the three modes, in particular between the water and highway modes. Obviously, the water and rail modes have to follow fixed routes. The highway mode is highly flexible due to the expanse of the network, but it is known that truckers have their preferred routes, and aim to minimize the total trip length, especially in longer hauls. Geographic Information Systems, using data from the National Transportation Atlas Database (NTAD)[12], are used to map and compare the lengths of the major river main stems with the most logical route that would most likely be chosen by trucks transporting barge commodities from an origin at one extreme of a river to a destination at the other extreme. Educated assumptions are made in regard to which truck routes would likely be preferred, with assistance from the Federal

[12] U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics. National Transportation Atlas Databases 2007.

Highway Administration's (FHWA) Estimated Average Annual Daily Truck Traffic[13], shown in Chapter 3. Conventional wisdom prescribes circuity factors of 1.3:1 for water trip length and 1.1:1 for rail trip length, with respect to the highway trip length from the same origin to the same destination. These ratios, though, are based on microscopic evaluations of individual trips. The comparative analysis found that trip length differences are minimal between trips of length approximately equal to an entire river's length and the corresponding long haul highway route that would be followed. In some instances the highway trip length is actually longer due to the absence of highway routes closely parallel to the adjacent river, simply because the presence of the latter makes the presence of the former redundant. For example, approximately 1,700 river miles have to be traveled by a barge along the Mississippi from Minneapolis to New Orleans. The corresponding southbound truck trip would most likely take place along Interstate 94, then Interstate 90, then Interstate 39, and finally Interstate 55, a total distance of about 1,900 miles, which is nominally longer than the Mississippi river route. Also according to NTAD, the Gulf Intracoastal Waterway, from Apalachee Bay, Florida to the Louisiana-Texas border is 640 miles long. The stretch of Interstate 10 that runs parallel to this stretch of GIWW is more than 600 miles long, indicating that the two modal routes are very similar in length. The comparative analysis was also conducted for the remaining waterways under study and led to similar conclusions. Allowing for possible deviations from the assumed preferred highway route, the long haul routes on the river and respective highway would be very comparable in total length. Therefore, any attempt to compensate for possible differences in modal route circuity was deemed unnecessary for the purposes of this study.

Further, it is assumed that in the event of a waterborne freight diversion to either truck or rail, the short haul, usually by truck, from the site to any mode's trunk line would still be present, at the same levels and on classes of roads similar to the current ones used for waterway access. These roads would most likely be major, four lane arterials (for example, U.S. or state highway routes). A diversion of all waterway freight to either truck or rail would require a truck haul of similar length from the site to the respective mode's major artery. Existing short hauls associated with access to the waterways would be offset by similar ones, to either the highway or the rail main line. Therefore, any compensation for differences relating to any aspect of short haul movements is considered unnecessary.

A logical consequence of a hypothetical waterborne freight diversion to either highway or rail would be a change in the transloading or intermodal facilities required. For example, in the absence of waterways, port facilities would become obsolete. At the same time the need for transloading facilities between local truck and long haul truck, between local truck and rail, or between long haul and shorter haul rail would arise. However, investigation of the chain reaction effects of a hypothetical freight diversion in regards to forecasting facility requirements is beyond the scope of this research study.

[13] Source: Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, accessible at http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/nat_stat.htm as of August 2007.

CHAPTER 2: CARGO CAPACITY

The dimensions of the units used to transport freight vary widely within each of the three modes (rail, truck, and inland waterway). In order to facilitate a meaningful cross-modal comparison, "standard" dimensions of the units used by each mode were defined. In comparing the modes, the *capacity* of the unit of transport was analyzed, not the average load. In this manner, all three modes were evaluated on the same scale.

The typical bulk commodity truck's body type, axle configuration, fuel, gross, tare, and cargo weight used in this report were confirmed by the Texas Motor Transportation Association[14]. This truck is a Heavy Duty Diesel Vehicle with a Gross Vehicle Weight Rating (GVWR) of 80,000 lbs which includes 50,000 lbs of cargo weight. The typical axle configuration is that of a typical tractor-trailer truck, i.e. an 18-wheeler, with a steering axle and two tandem axles, or five total axles.

This cargo weight is assumed to be roughly equal for liquid or dry bulk cargo. The densities of representative bulk commodities were investigated to ensure that the volume of a 50,000 lb net cargo weight is commensurate with the maximum tank truck volume of about 8,500 gallons. For example, 50,000 lbs of gasoline, at a density of 6.2 lbs/gal, would occupy a volume of 8,065 gallons. The process was repeated for a number of representative bulk commodities commonly transported by barge. The results confirmed that trucks carrying these heavy liquid or dry bulk commodities weigh out before cubing out. Therefore, this study assumes that the trucks that would transport this cargo in case of a waterway closure will be constrained by weight limits; thus, the maximum allowable cargo weight is assigned.

For the same reason, only railcars used for carrying bulk commodities are taken into consideration. Even among this type of railcars, there is significant variation in carload capacities depending on the specific commodity. According to the Association of American Railroads the average carload for coal, which is the dominant non-liquid commodity for both rail and inland barge traffic, was 112.5 tons in 2006. Industry statistics also show that general purpose tank cars carry up to 125 tons. The expert panel assembled as a part of this research effort reached the conclusion that with the wide range of capacities in the existing railcar fleet, these figures should be adjusted downward to 110 tons per car.

Barge data were acquired from the Corps of Engineers' Navigation Data Center (NDC) Vessel Characteristics File for 2005. The most common dimensions of barges carrying dry bulk (either covered or open) are 200 ft x 35 ft, followed by 195 ft x 35 ft. These two types represent 49% and 43% of the dry bulk barge population in the database respectively. Industry contacts report that the trend in recent years has been to construct larger barges, so the 200 ft barges are used as the "standard" barge in this report. The average cargo capacity for these barges is 1,757 short tons, rounded down to 1,750 tons for use in this study.

[14] Telephone consultation with TMTA staff. March 2007. http://www.tmta.com.

Also according to the same database, 195 ft x 35 ft barges constitute 22% of the total tank barge fleet while ~300 ft x 54 ft barges constitute 21% of the total barges carrying liquid bulk. Capacities are reported in tons, which can be converted to barrels by using the weight of each commodity per barrel (lbs/bbl). Using a range of 6 lbs/gal to 7.3 lbs/gal, barrel weights may range from 252 lbs/bbl to 307 lbs/bbl respectively. Table 1 shows approximate carrying capacities for tank barges:

Table 1. Tank Barge Capacities

Dimensions (feet)	Average Cargo Weight (tons)	Number of Barrels	
		Minimum	Maximum
195 x 35	1,487	9,687	11,802
~300 x 54	3,935	25,635	31,230

Discussions with a leading tank barge operator revealed that new tank barge construction is primarily of the ~300 ft x 54 ft barge. This type of barge can hold an average of 28,433 barrels. An examination of barges operated by Kirby Inland Marine indicated that this may be slightly too high; therefore, this study uses a more conservative 27,500 barrels as the capacity of a typical tank barge.

The "standard" capacities for the various freight units across all three modes that are used in this analysis are summarized in Table 2.

Table 2. Standard Modal Freight Unit Capacities.

Modal Freight Unit	Standard Cargo Capacity
Highway – Truck Trailer	25 tons
Rail – Bulk Car	110 tons
Barge – Dry Bulk	1,750 tons
Barge – Liquid Bulk	27,500 bbl

Barges obviously have a higher cargo carrying capacity per unit than do trucks or railcars. Figure 4 illustrates the carrying capacity of a dry cargo barge in comparison with the rail and truck modes.

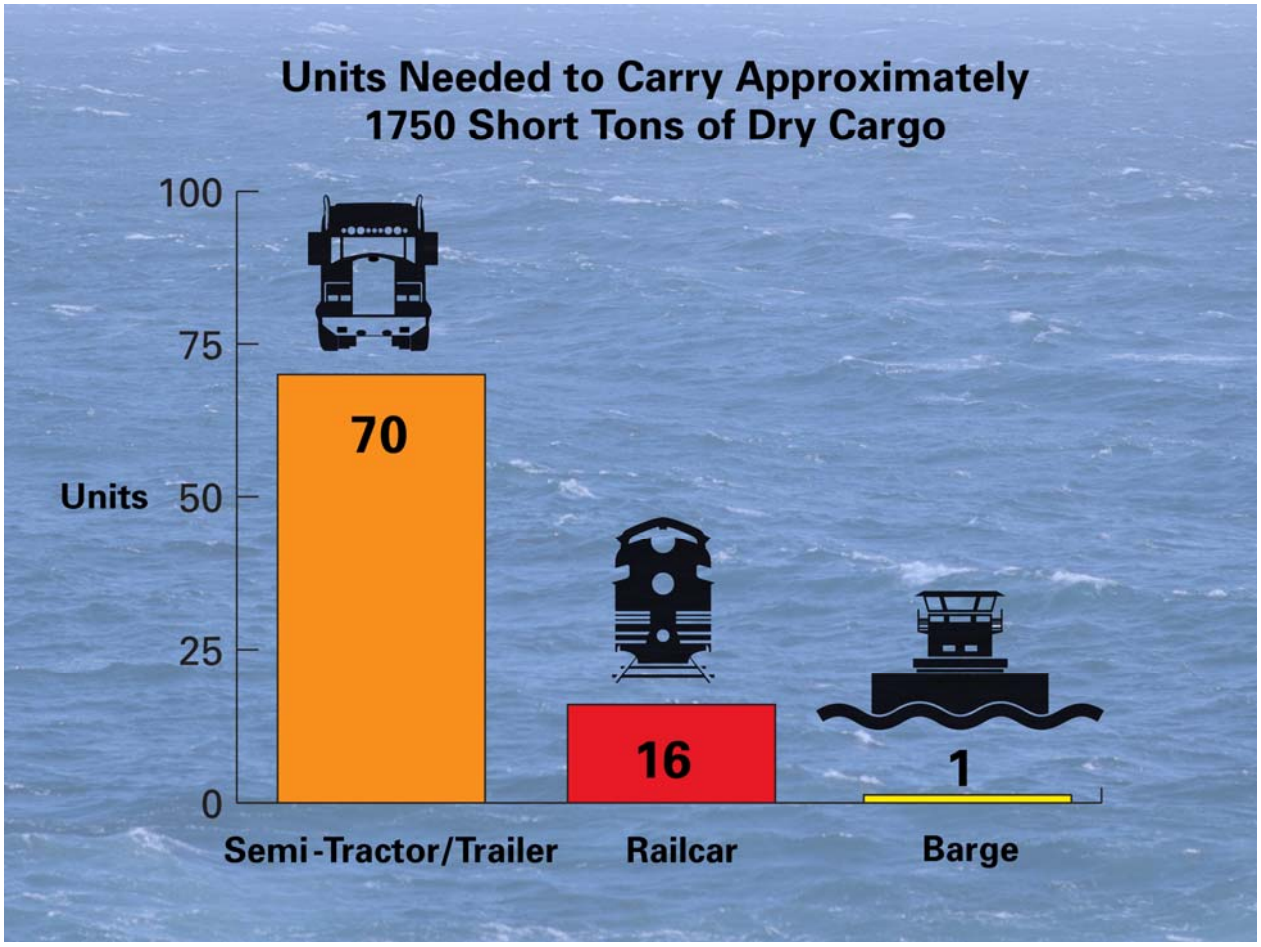

Figure 4. Dry Cargo Capacity Comparison.

Figure 5 illustrates the carrying capacity of a liquid cargo barge in comparison with the rail and truck modes.

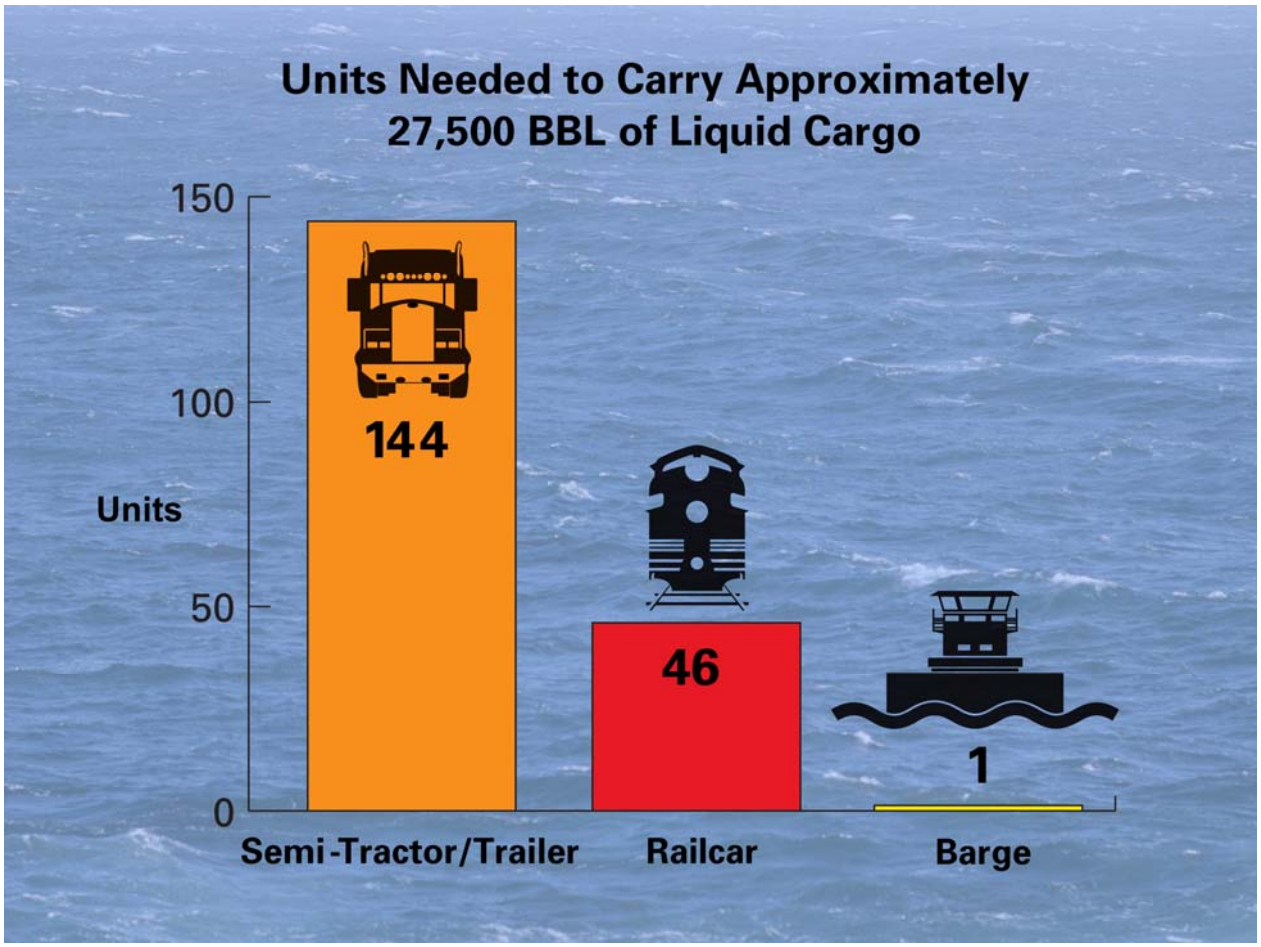

Figure 5. Liquid Cargo Capacity Comparison.

It is difficult to appreciate the carrying capacity of a barge until one understands how much demand a single barge can meet. For example, a loaded covered hopper barge carrying wheat carries enough product to make almost 2.5 million loaves of bread, or the equivalent of one loaf for almost every person in the state of Kansas. (See Figure 6.)

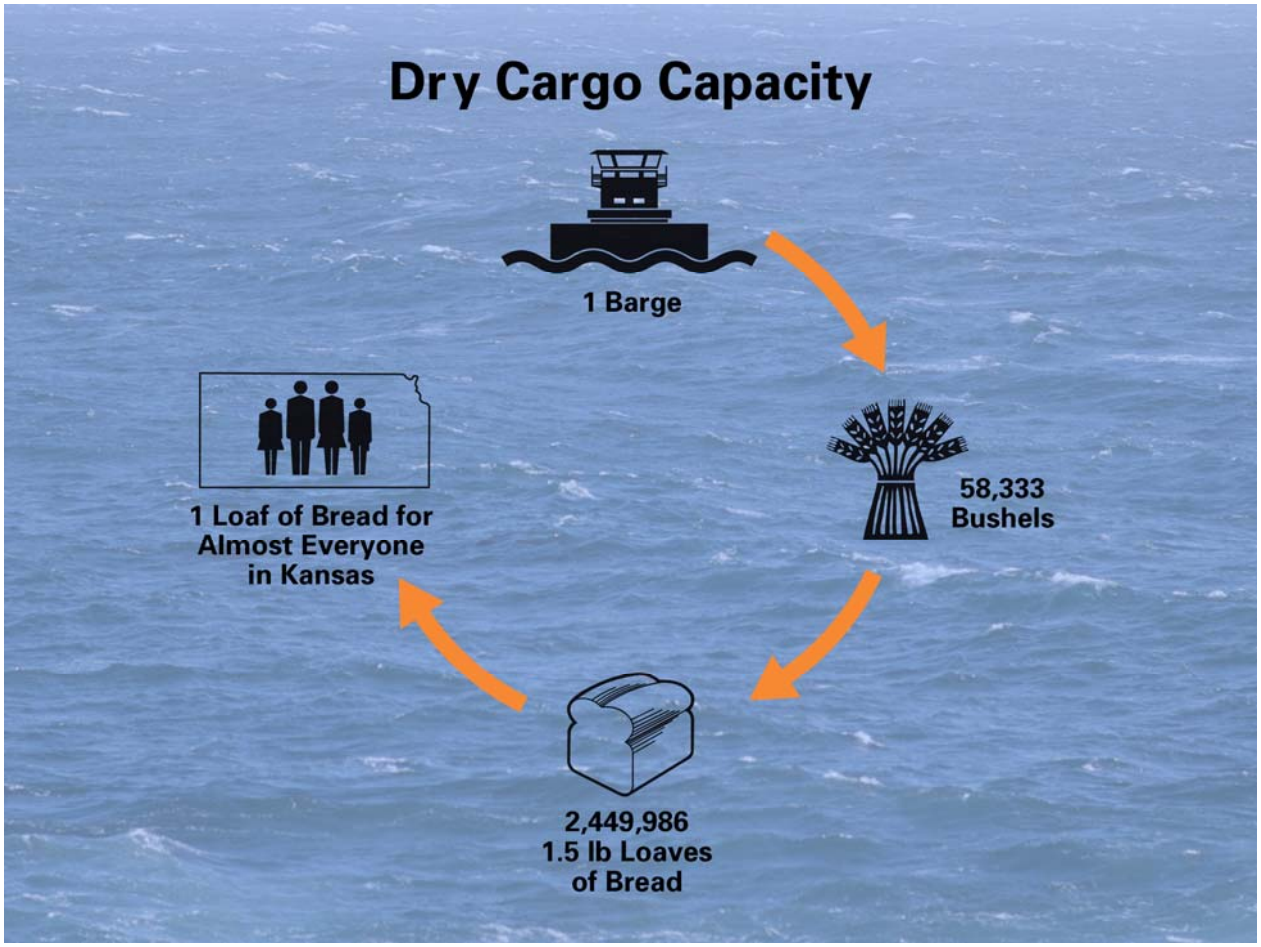

Figure 6. Wheat Illustration.

A loaded tank barge carrying gasoline carries enough product to satisfy the current annual gasoline demand of approximately 2,500 people. (See Figure 7.)

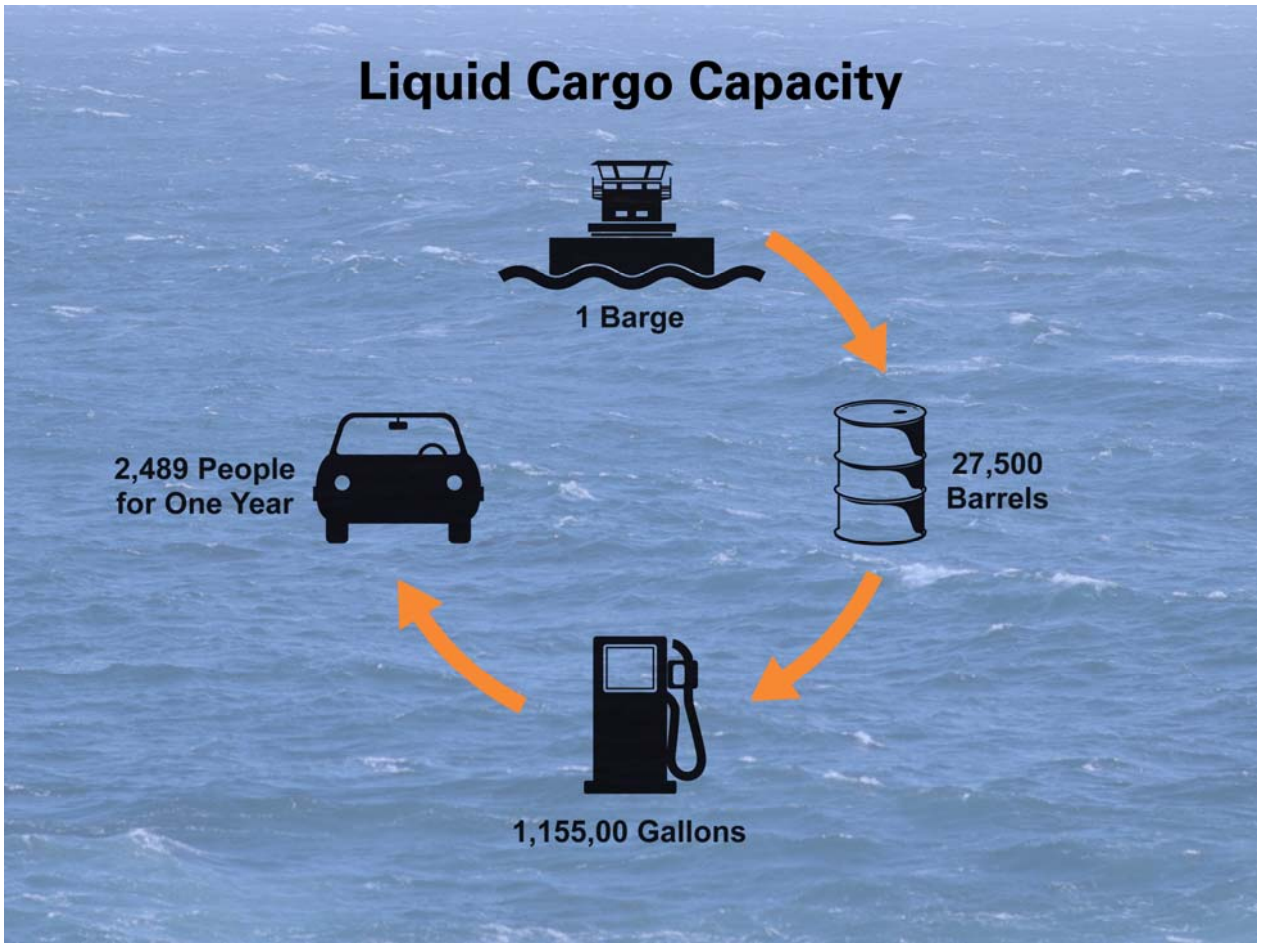

Figure 7. Gasoline Illustration.

Table 3 presents a tabulated comparison of the dimensions and capacities of the modal freight units to better understand the differences in the order of magnitude among the three modes:

Table 3. Modal Cargo Capacity Comparison.

Modal Freight Unit	Freight Unit Configuration	Length (feet)	Cargo Capacity (tons)
Tow (Dry Cargo)	15-barge tow (5x3)	1,072	26,250
Unit Train	108 cars, 3 locomotives	6,054	11,880
Truck	One tractor with a 53 ft trailer	70	25

It is common to see tows of 15 barges or more on the major river systems. Figure 8 illustrates the carrying capacity of a 15-barge tow of dry cargo.

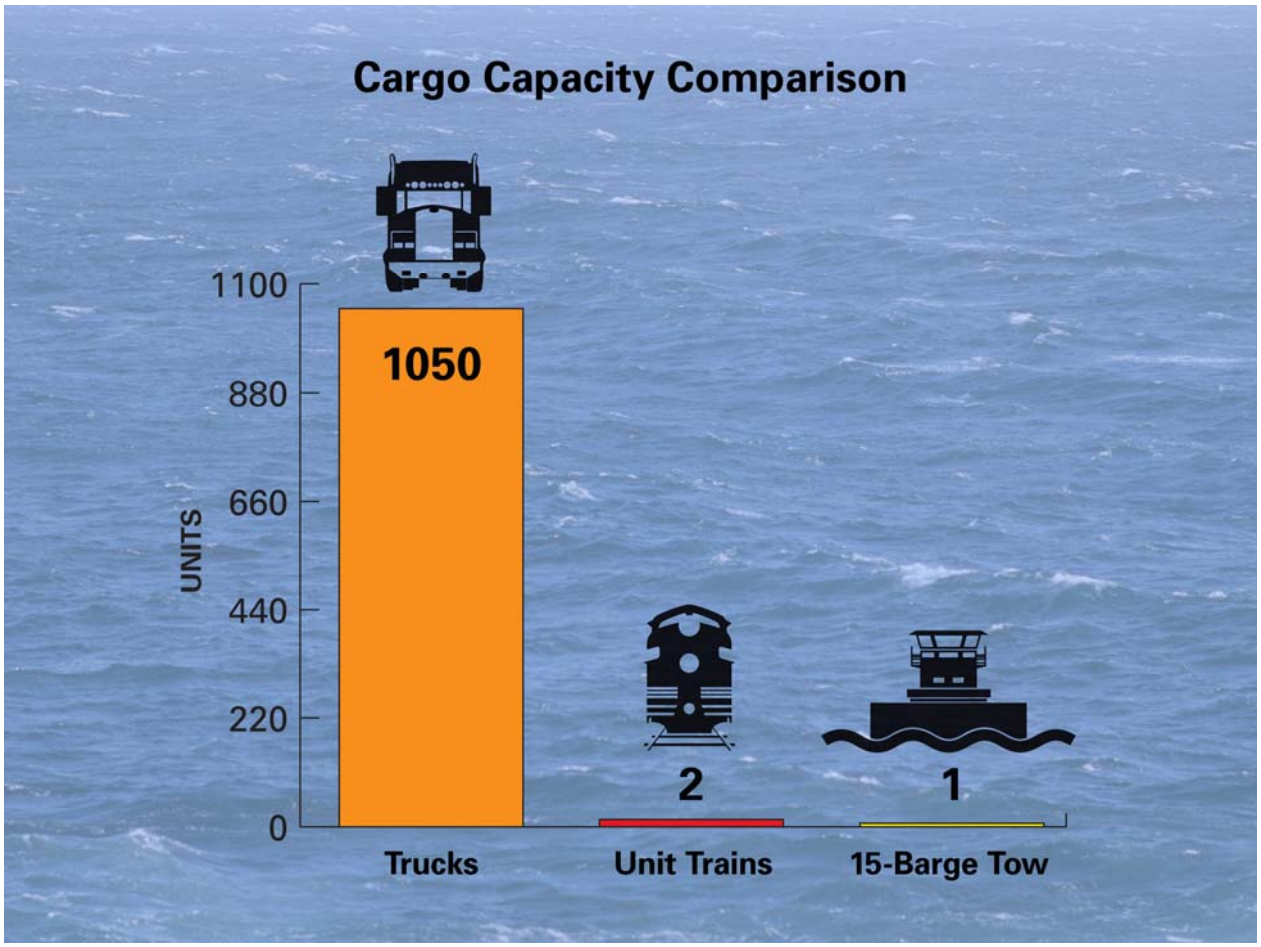

Figure 8. Capacity of 15-Barge Tow.

If the total domestic inland waterway tonnage (624 million tons) were loaded into the modal configurations indicated above at their maximum carrying capacity, and then the units were lined up end-to-end, the line of barges would extend more than 4,800 miles, the line of trains would extend 60,000 miles (2.4 times around the equator), and the line of trucks would extend 331,000 miles (13.3 times around the equator).

CHAPTER 3: CONGESTION ISSUES

BACKGROUND

In the event of a major waterway closure, cargo will have to be diverted to either the rail or highway (truck) mode. The location of the closure and the alternative rail and highway routes available for bypass will determine any predominance in modal share. The geographical extent of the waterway system network does not allow for any realistic predictions to be made in regards to a closure location, the alternate modal routes available for bypass, or the modal split. As a result, this analysis adopts the all-or-nothing modal assignment principle. The evaluation considered the possible impacts resulting from either a theoretical diversion of 100% of the current waterborne cargo to the highway mode OR a theoretical diversion of 100% of the current waterborne cargo to the rail mode.

As mentioned earlier, cargoes moved on the inland waterways are typically bulk commodities with low unit values. This characteristic has a strong influence on the types of railcars and trucks that would be chosen to transport freight diverted from the waterways. The distribution by commodity groups in 2005 as shown in Figure 3 is reproduced below.

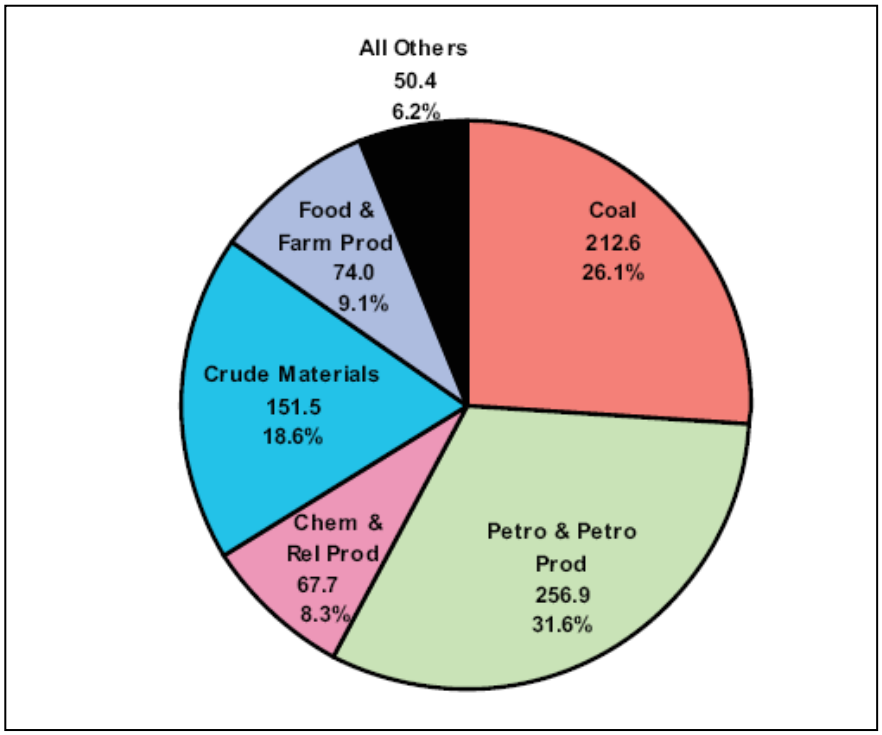

Figure 9. 2005 Barge Traffic by Commodity Group (in millions of tons).
Source: Waterborne Commerce of the United States, Calendar Year 2005, Part 5–National Summaries, U.S. Army Corps of Engineers

HIGHWAY

The latest national waterborne commerce[15] data published by the U.S. Army Corps of Engineers Navigation Data Center were obtained for calendar year 2005. The tonnage and ton-mile data for the following major rivers were extracted:

- Mississippi River - Minneapolis to Mouth of Passes
- Ohio River
- Gulf Intracoastal Waterway (GIWW)
- Tennessee River
- Cumberland River
- Columbia River system – Columbia and Snake rivers

The tonnage and ton-mile data were then used to develop estimates of the equivalent truckloads, truck trips, and vehicle miles traveled that would be required if all waterway freight transported on these major rivers were to be transported by truck. All waterway data and estimated truck equivalent values are shown in Table 4. (The table assumes a cargo weight of 25 tons per truckload.) Vehicle miles traveled (vmt) is the typical unit of measure for highway travel and is simply the number of vehicles passing a point on the highway multiplied by the length of that segment of highway, measured in miles and usually on the order of one mile.

Table 4. Waterway and Truck Equivalents – 2005 Tonnage and Ton-miles.

Waterway	Tonnage (x 000)	Ton-miles (x 000)	Trip Length (miles)	Annual Truckloads	Annual Truck Trips	Annual Loaded Truck vmt	Total Annual Truck vmt
Mississippi	270,270	153,815,506	569	10,810,800	21,621,600	6,152,620,240	12,305,240,480
Ohio	249,213	59,895,324	240	9,968,520	19,937,040	2,395,812,960	4,791,625,920
GIWW	115,768	18,523,919	160	4,630,720	9,261,440	740,956,760	1,481,913,520
Tennessee	53,225	5,806,012	109	2,129,000	4,258,000	232,240,480	464,480,960
Cumberland	23,418	2,520,436	108	936,720	1,873,440	100,817,440	201,634,880
Columbia/Snake	13,129	546,925	42	525,160	1,050,320	21,877,000	43,754,000
Total	**725,023**	**241,108,122**	**--**	**29,000,920**	**58,001,840**	**9,644,324,880**	**19,288,649,760**

Waterway tonnage and ton-mile data were taken from NDC. Average trip length in miles on each waterway was then calculated by division of ton-miles by miles. In reality, though, the number would denote both the average barge and truck trip length, since highway miles have been assumed to be on a 1:1 basis with river miles. Annual truckloads were calculated by dividing the tonnage for each waterway by 25 tons/truck. They were then doubled to account for an equal number of empty return trips. The truck vehicle miles traveled can be calculated in either of two ways that result in the same figure. Ton-miles can be divided by 25 tons/truck and the result doubled - to account for the empty backhaul - or the trip length can be multiplied by the annual truck trips, which has already incorporated the loaded as well as the empty return trips.

[15] U.S. Army Corps of Engineers. Navigation Data Center. Waterborne Commerce of the United States 2005.

Trucks that carry bulk commodities are fairly limited in the backhauls they can attract. For example, a grain truck will not return with steel or any liquid product. Therefore, this theoretical diversion scenario assumes that all trucks would return empty - a 100% empty backhaul. The exact percentage of empty backhaul for existing truck operations has rarely been precisely determined, but it is thought to be around 30-35%. Currently, however, trucks primarily haul break bulk cargo which would make a non-empty return trip possible. On the other hand, tank trucks and certain commodity carriers tend to return empty. For example, a tank truck that had previously hauled nitrogen gas is unlikely to haul anhydrous ammonia on its return trip. Therefore, for this study, the annual truck trips are estimated at two times the annual truckloads.

Historical data for roadway congestion trends (rural interstate traffic) and intercity truck ton-miles[16] were obtained in order to enable estimation and prediction of the possible roadway congestion effects due to a hypothetical diversion of river ton-miles to truck ton-miles. The rationale behind examining this particular relationship is that waterway movements are long distance ones, and the equivalent long distance truck movements would occur primarily on interstate highways that pass through rural settings located between urban areas.

The data range used in this analysis is from 1996 through 2003. This is the only period for which all sources provide data. Annual national historic data for intercity freight truck ton-miles over this period were obtained from the Bureau of Transportation Statistics (BTS)[16]. National historic data for Weighted Average Daily Vehicles per lane on rural interstates were obtained from Highway Statistics 2005[17] for respective years. The published vehicle traffic data include all vehicle types and are already weighted by the length of the segment over which the traffic was measured, as length varies among road segments. Table 5 tabulates the data extracted for this analysis.

Table 5. Intercity Truck Ton-Miles vs. Rural Interstate Vehicle Traffic.

Year	Intercity Truck (Billion Ton-miles)	Weighted Average Daily Vehicles per Lane Rural Interstate[17]
1996	1,071,000	4,630
1997	1,119,000	4,788
1998	1,149,000	5,010
1999	1,186,000	5,147
2000	1,203,000	5,272
2001	1,224,000	5,381
2002	1,255,000	5,511
2003	1,264,000	5,465

[16] Bureau of Transportation Statistics. National Transportation Statistics 2006. Appendix A, Truck Profile, Performance, Revised April 2006. December 2006.

[17] Federal Highway Administration. Highway Statistics 2005. Section V: Roadway Extent, Characteristics, and Performance. System Congestion Trends (Chart).

Linear regression techniques were then applied to the historical data to develop an equation describing the relationship between these two variables. Figure 10 shows the line fitted, the equation developed, and the R^2. (R-squared, the coefficient of determination, is the proportion of variability in a data set that is accounted for by a statistical model.). The R^2 is very close to 1, which indicates that the line is a very good fit to the data. In other words, there is a very strong relationship between values of Average Daily Vehicles per Lane on rural interstates and Intercity Truck Ton-miles, with the former historically dependent on the latter.

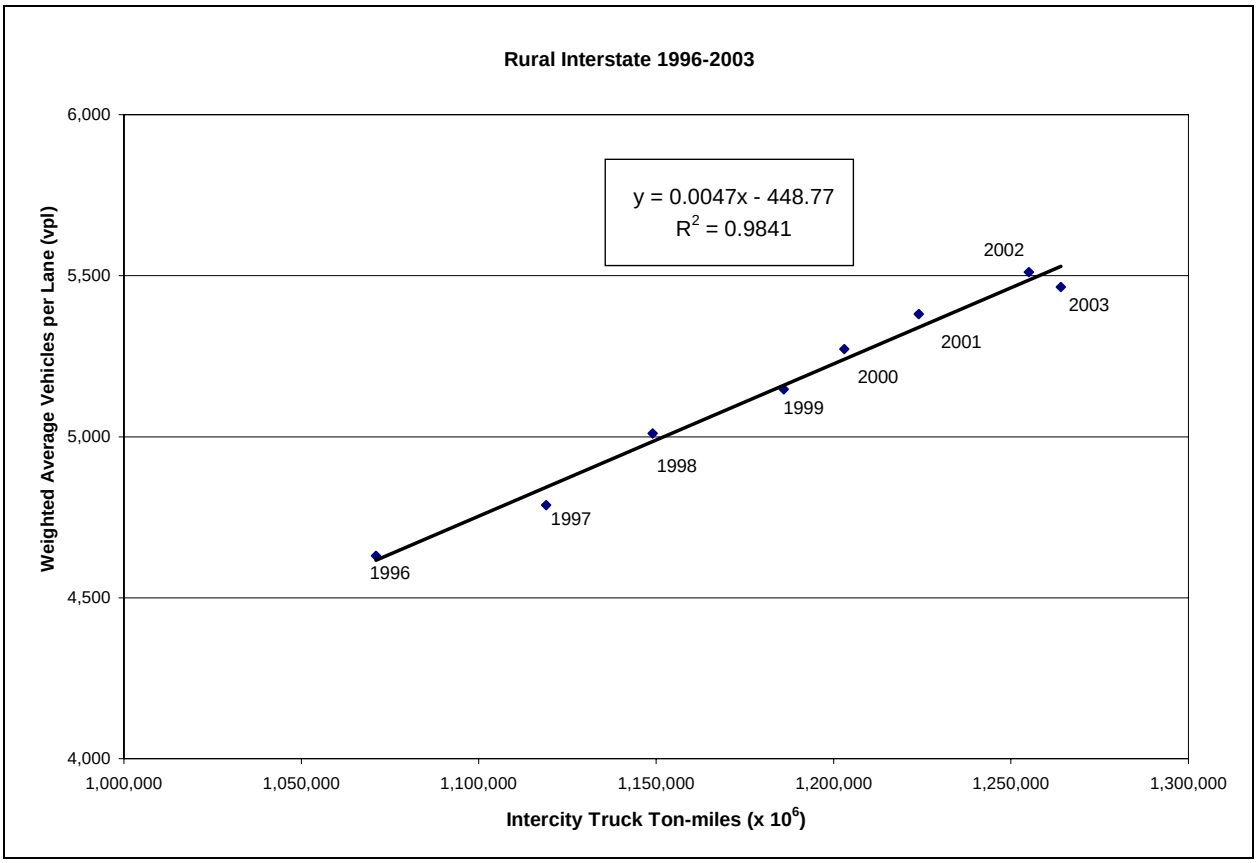

Figure 10. Average Daily Vehicles per Lane of Rural Interstate vs. Intercity Truck Ton-miles.

In 2003 there were 5,465 Average Daily Vehicles per Lane on Rural Interstates, as shown in Table 5 above. Highway Statistics[18] reports that on rural interstates, in the same year, 84% of daily traffic (or 4,591 vehicles) was composed of passenger cars, buses, and light and heavy single unit trucks. The remaining 16% of the traffic (or 874 vehicles) were combination trucks, the types of trucks that would carry diverted waterborne freight.

The total ton-miles transported on the chosen waterways in 2005 were 241,108,122 thousand – or 241,108.122 million. The total ton-miles transported by intercity trucks in 2003 (latest available data) were 1,264,000 million. If the waterway ton-miles are diverted to trucks, the new total ton-miles attributed to intercity trucks adds up to 1,505,108.122 million. When this number

[18] Federal Highway Administration. Highway Statistics 2005. Section V: Roadway Extent, Characteristics, and Performance. Percentage Distribution of Traffic Volumes and Loadings on the Interstate System, Table TC-3.

is input to the developed regression equation, the Weighted Average Daily Vehicles per Lane on Rural Interstates increases to 6,625. Since the number of passenger cars, buses, light trucks, and heavy single unit trucks are constant at 4,591 vehicles per lane, the remaining 2,034 vehicles would be combination trucks. Thus, the percentage of daily traffic that is combination trucks rises from 16% to 30.7%. In other words, the hypothetical diversion of current waterway freight traffic would add 1,160 combination trucks (to the current 874) per day per lane on a typical rural interstate.

Diversion of waterborne freight to highways could more than double the number of heavy trucks on the average rural interstate.

In summary, the amount of cargo currently transported by the Mississippi main stem, Ohio main stem, Gulf Intracoastal Waterway, Tennessee River, Cumberland River, & Columbia River, is the equivalent of 58,000,000 truck trips annually that would have to travel on the nation's roadways in lieu of water transportation. This increase in truck trips would cause the Weighted Average Daily Combination Trucks per Lane on segments of interstate between urban areas to rise by 133% on a nationwide basis.

This increase was derived from national level data and reflects an average nationwide increase. The absolute number and percent combination trucks per lane of rural interstate located in the vicinity of the waterways under study would likely be higher than average. Truck traffic due to the diverted waterborne freight would undoubtedly be concentrated in the corridors that are parallel to the major rivers, especially the outer lane, which tends to be used by trucks more heavily. Thus, the impact in the vicinity of the waterways considered in this study would logically be more severe than the national average, especially during the heavier truck travel periods of the year, month, week, or day.

Major waterways help avoid the addition of 58 million truck trips to our highway system annually.

Figure 11 shows truck traffic levels on the nation's major highways, while Figure 12 shows the locations of the major bottlenecks.

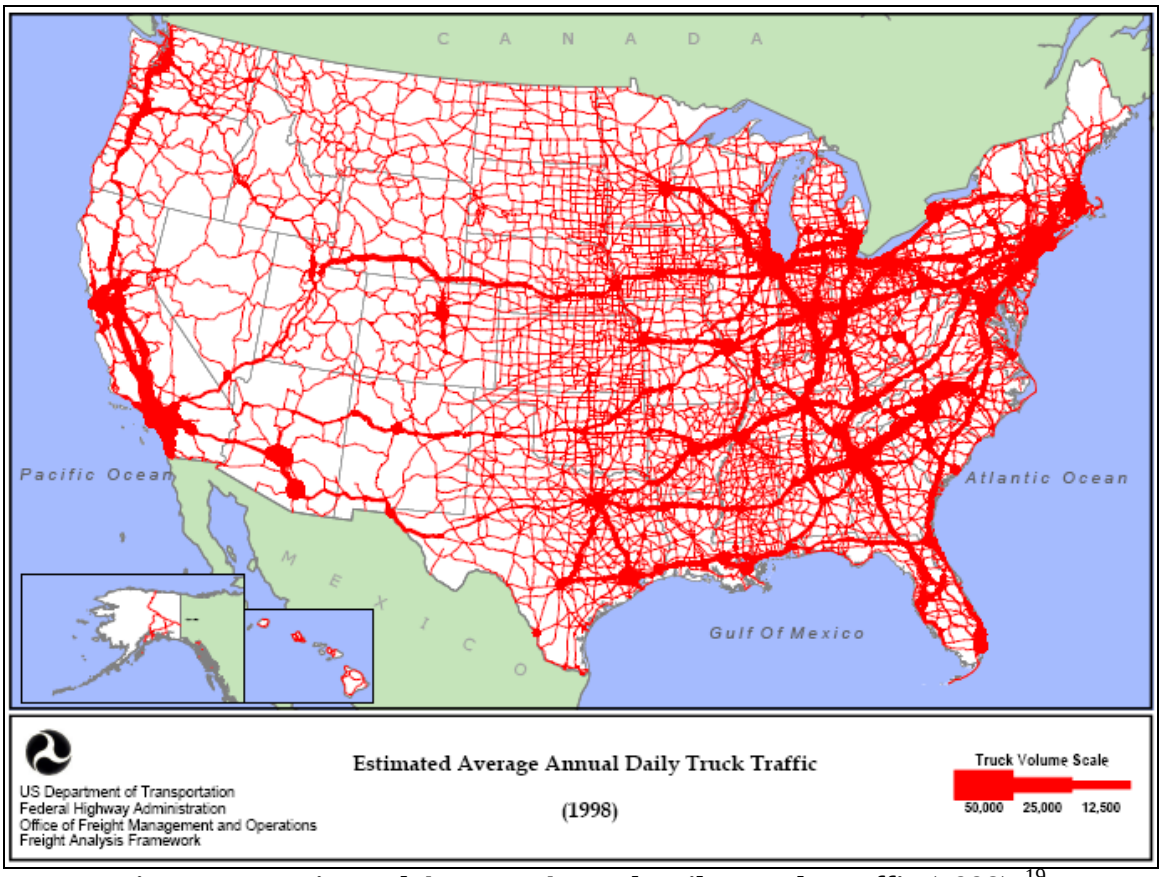

Figure 11. Estimated Average Annual Daily Truck Traffic (1998).[19]

Source: Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework

[19] Source: Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, accessible at http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/nat_stat.htm as of August 2007.

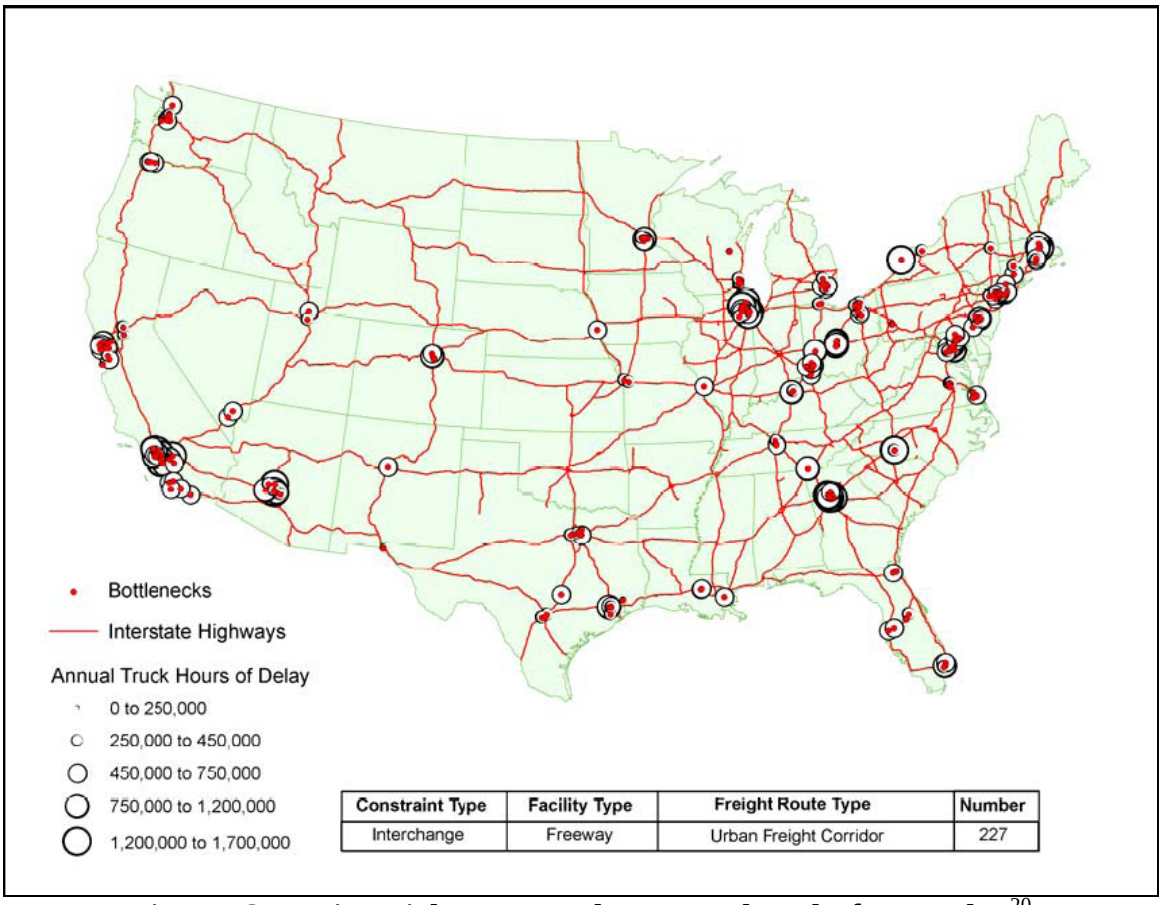

Figure 12. Major Highway Interchange Bottlenecks for Trucks. [20]
Source: An Initial Assessment of Freight Bottlenecks on Highways. Federal Highway Administration, Office of Transportation Policy Studies.

Data Limitations and Necessary Assumptions

The hypothetical and non-traditional nature of this study requires the adoption of several important assumptions in order to permit usage of existing data that could support a sound analysis.

First, the expanse of the roadway network in relation to the waterway or rail networks could not rationalize link assignment of the new truck traffic to a road class other than the interstate system. In addition, regional or corridor data are not available and analysis at an inter- or multi-state geographical level could not be supported. The use of national data is considered to be the only appropriate basis given the scope of this study.

Second, it is necessary to assume that traffic delay is uniform along interstate segments regardless of whether they are classified as urban or rural. The rationale is that these long-haul combination trucks are likely to avoid urban cores that would lead to additional trip delay and

[20] Cambridge Systematics Inc. and Battelle Memorial Institute. An Initial Assessment of Freight Bottlenecks on Highways. Federal Highway Administration, Office of Transportation Policy Studies. October 2005.

travel on urban bypasses, which carry less passenger car traffic. The higher traffic volumes in urban areas and subsequent congestion are primarily attributed to a higher number and percentage of passenger cars in the traffic stream. The absolute number of trucks may be equal to the rural interstate segment downstream; however, their percentage of the traffic volume drops around urban areas due to the domination of passenger cars in the traffic stream.

Third, it is assumed that the shorter hauls to/from interstate truck routes are of similar length and other characteristics to the existing shorter hauls to/from river segments and take place on the same road classes, which are primarily major arterials other than the interstate system. Therefore, compensation due to this issue is considered unnecessary.

Finally, it is assumed that sufficient tractors, trailers, drivers, and other equipment will be available to move diverted cargo by truck. Trade journals such as the Journal of Commerce are reporting that there may be a serious shortage of truck drivers and of equipment for both truck and rail movements in the near term. Realistically, demand levels would most likely soar and, when chain reaction effects are factored in, a serious disruption to the entire supply chain could occur. However, an analysis of this type and complexity is outside the scope of this study.

RAIL SYSTEM CONGESTION IMPACTS

The intent of this rail system congestion analysis is to provide an estimate of the impact that a closure of the inland river transportation system would have on the railroad industry and the potential impact to the transportation of commodities in particular.

According to the Energy Information Administration, "In 2001, railroads delivered 68.5% of coal shipments to their final electric utility destinations, followed by water (13.1 %); conveyor belts, slurry pipeline, and tramways (9.3 %); and truck (9.2 %)."[21] The market growth in coal transportation for the railroad industry has grown rapidly in recent years. In 2006 railroads transported a record 852 million tons of coal, which is 6% greater than the previous record established in 2005. Because the demand for electricity has also continued to grow in recent years, this analysis assumes that the market share for each transportation sector has remained relatively stable since the 2001 study.

Data on unit and grain train velocities as well as available cars on-line were extracted from the published operating statistics for the current 53-week period on the Association of American Railroads (AAR) website[22]. The history data for cars on-line and train velocities were obtained from both U.S. Securities and Exchange Commission (SEC) Annual 10-K Forms and Surface Transportation Board (STB) R-1 Report filings. Railroad train velocity by commodity for the Class I railroads is available on a 53-week history from the AAR. The system velocity for all trains is reported by individual railroads in their annual reports on an inconsistent basis. In order to establish a general train speed for commodity trains east of the Mississippi River and another

[21] Source: Energy Information Administration, http://www.careenergy.com/technology/transportation.asp, August 2007

[22] Source: AAR website, individual railroads performance measure, 53 week tab, 07/07/06-07/06/07, http://www.railroadpm.org/ as of August 2007

for those west of the river, the current 53-week (2007) individual railroad performance measures are used.

The railroads were divided into entities operating principally east (Eastern) or west (Western) of the Mississippi river for the principal fact that their unit and grain train markets are located east or west of the river. Railroads operating east of the Mississippi typically have a shorter unit train trip length and slower train velocities than the Western roads. Both the Eastern and Western railroads have operations on both sides of the river, and it is not the intent of this research to imply any limited operating area for the railroads because of the location of the Mississippi river.

For Eastern Class I railroads (Canadian National Railway--CN, CSX Transportation Inc.--CSX, and Norfolk Southern Corp.--NS), the weighted average coal train velocity is currently 17.04 miles per hour. The weighting factor is based on the individual railroad's share of reported gondola cars on-line in the current 53-week tracking data. The R-1 reported train velocities for the years 2003, 2004, and 2005 indicate a continuing decrease in unit train velocities as unit train business increases year by year.[23]

For the Western Class I railroads (Burlington Northern Santa Fe Railway--BNSF, Canadian Pacific Railway--CPR, Kansas City Southern Railway Company--KCS, and Union Pacific Railroad Company--UP) the weighted average coal train velocity is currently 19.78 miles per hour. The 2003, 2004, and 2005 R-1 reports for unit train velocities for the Western railroads also indicate a continuing decrease in unit train velocities as unit train business increases year by year.

The tonnage moved on the inland river system would amount to an addition of nearly 25% more tonnage on the railroad system. This new burden would not be evenly distributed. The primary burden would be placed on the Eastern U.S. railroads with little real opportunity to take advantage of excess capacity that may exist on the Western U.S. railroads.

Diverting river traffic would add 25% more tonnage to the national rail system.

The coal traffic on the Ohio River provides a clear example of what the effect of a major diversion of traffic would be. Referring to Figure 9 above, the total waterborne barge coal commodity tonnage in 2005 was 212.6 million tons, which was 26.1% of all barge tonnage. The Ohio River coal traffic was reported to be 133.1 million tons for the year 2005. The Ohio River coal traffic represents only 16.3% of the total inland waterway barge tonnage, but it is 62.6% of the barge coal tonnage for the year. The majority of the Ohio River coal traffic would have to be handled by the CSX railroad if the Ohio River transportation system ceased operations. The CSX lines essentially parallel the Ohio River while the NS Railway lines are principally perpendicular to the river.

If the 133.1 million tons of Ohio River coal traffic were to be shifted to the CSX rail lines, the railroad would be faced with an additional 1,010,250 car loadings of coal annually with 112 tons of coal in each car. If the trains were made up of 108 cars per train there would be an annual addition of 9,354 train movements or 25.6 added train movements per day on the lines

[23] STB website, http://www.stb.dot.gov/econdata.nsf/f039526076cc0f8e8525660b006870c9?OpenView as of August 2007

paralleling the Ohio River. Given the average round trip time of a unit coal train of three days, the railroad would be faced with an additional burden of at least 8,300 additional coal cars to meet this new traffic. There would be an additional 76 unit trains of 108 cars each on the Ohio River region of the CSX Railroad to meet the new traffic demand of the Ohio River coal tonnage.

The CSX Railroad Annual Reports provide statistical data for average train velocity, average system dwell time, and total number of cars-on-line for the period between 2001 and 2005. The data are shown in Table 6.[24] (The dwell time is the average amount of time between when a car arrives in a rail yard and when it departs the rail yard.[25])

Table 6. CSX Railroad Performance Measures.

CSX Transportation						
	2001	2002	2003	2004	2005	With Diversion
Velocity	21.7	22.5	21.1	20.3	19.2	12.88
Dwell time	24.5	23.2	25.3	28.7	29.7	NA
Coal car loadings	1,722,000	1,574,000	1,570,000	1,659,000	1,726,000	2,736,000

An exponential regression analysis indicates the addition of 1,010,250 coal car loadings shifted from the Ohio River to the CSX Railroad would reduce the system average train velocity from 19.2 mph downward to 12.88 mph at a coal car loading requirement of 2,736,000 units that would maintain the 2005 railroad traffic volume with the additional river tonnage. (See Figure 13.)

[24] All data, except With Diversion column excerpted from http://investors.csx.com/phoenix.zhtml?c=92932&p=irol-reportsannual .
[25] CSX Annual Report, 2003, p 10, http://media.corporate-ir.net/media_files/irol/92/92932/annual_reports/2003AR.pdf .

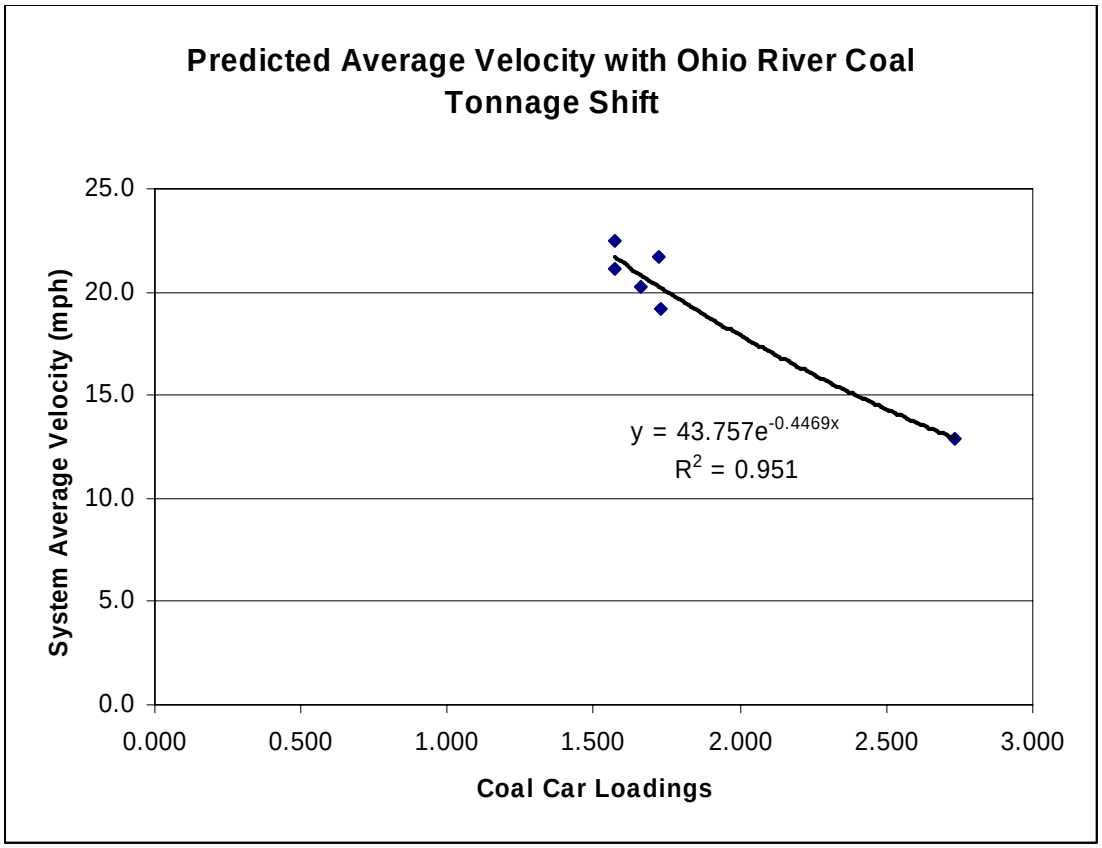

Figure 13. Predicted CSX train velocity with addition of Ohio River coal tonnage.

The exponential curve fit analysis indicates an R^2 correlation coefficient of 0.951, which implies a likely outcome given the assumptions applied to the regression. Other regression analyses were carried out but resulted in low correlation coefficients, below 0.400. It should be noted that the annual coal loading data and train velocities from the years 2001 to 2005 are for the entire CSX Railroad system. The actual CSX coal traffic train routes and route densities for the period between 2001 and 2005 is unknown.

For the projected increased coal loadings from closing the Ohio River barge traffic, it can reasonably be assumed that the 58% increase in railroad coal loadings will originate and terminate up or downstream in the vicinity of the Ohio River. Given that the added traffic would use only rail lines along the Ohio River, using the CSX System average train velocity is the best available metric to evaluate the impact on rail traffic. The potential for increased coal rail traffic due to closing the Ohio River transportation system would impact the local rail lines much more severely than the rest of the system. The real possibility exists that the railroad system as currently developed could not respond by accommodating the shift of coal traffic and it would either end up in gridlock or very little additional coal traffic could be accommodated.

CHAPTER 4: EMISSIONS ISSUES

The first part of this chapter focuses on four primary pollutants that are tracked by the Environmental Protection Agency: hydrocarbons, carbon monoxide, nitrogen oxide, and particulate matter. An analysis of Greenhouse Gas (GHG) emissions is included at the end of this chapter.

HIGHWAY

The Environmental Protection Agency's (EPA) MOBILE6 model[26] estimates mobile source emission factors for several hazardous air pollutants, in grams per vehicle mile traveled. These air pollutants include hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM), and carbon dioxide (CO_2). Mobile sources are simply gasoline fueled and diesel fueled highway motor vehicles.

Basic emission rates developed from national vehicle fleet data are updated with each version of MOBILE to reflect changes in vehicle, engine, and emission control system technologies; changes in applicable regulations, emission standards, and test procedures; and improved understanding of in-use emission levels and the factors that influence them. The model allows modeling of specific, tailored situations via user-defined inputs that complement the basic emission factors (for example, a specific roadway type, time of day, vehicle category, etc.).

Emission factor estimates depend on various conditions, such as ambient temperatures, altitude, travel speeds, operating modes, fuel volatility, and mileage accrual rates. Many of the variables affecting vehicle emissions can be specified by the user. MOBILE6 estimates emission factors for any calendar year between 1952 and 2050, inclusive. Vehicles from the 25 most recent model years are considered to be in operation in each calendar year. On-road vehicles are classified into 28 vehicle classes that include passenger cars, light and heavy duty trucks, buses, and motorcycles.

MOBILE models have been used by the EPA to evaluate highway mobile source control strategies; by states and local and regional planning agencies to develop emission inventories and control strategies for State Implementation Plans under the Clean Air Act; by metropolitan planning organizations and state transportation departments for transportation planning and conformity analysis; by academic and industry investigators conducting research; and in developing environmental impact statements.

The emissions analysis for this project utilizes MOBILE6.2, which was run twice to model two situations – the existing scenario and the hypothetical scenario that assumes diversion of barge traffic onto roadways, on an average summer day in 2005, the waterborne data year.

Identical values for the minimum required inputs were used for both runs in order to ensure consistency. They are the following:

- Calendar year: 2005

[26] U.S. Environmental Protection Agency. Office of Transportation and Air Quality. User's Guide to MOBILE6.1 and MOBILE6.2. EPA420-R-03-010. August 2003.

- Month: July
- Minimum/maximum temperature: 60.0˚ F/90.0˚ F
- Altitude: low
- Fuel Reid Vapor Pressure: 9.0 psi (pounds per square inch) (average value across the study area in summer months)
- Diesel Fuel Sulfur Content: 500 ppm (parts per million)

In both runs, emission factors were estimated in grams per vmt by vehicle class and for the following pollutants:

- Hydrocarbons (HC – expressed as Volatile Organic Compounds, VOC)
- Carbon Monoxide (CO)
- Nitrogen Oxides (NO_x)
- Carbon Dioxide (CO_2)
- Particulate Matter of diameter 10 micrometers or less (PM-10)

The first run was the baseline or default run. All other inputs that can be user defined, such as vmt distribution by vehicle class, roadway type and hour of day, were left intact, i.e., the model's built-in default values derived from national fleet and vehicle activity data were used.

The second run modeled only the fleet of the additional trucks that would be required in the event of a diversion. The emission factors of these vehicles operating under diversion conditions differ from the values obtained from the default run, which are based on national average activity patterns - or existing conditions. Under diversion the additional fleet's travel activity is assumed to occur almost exclusively on interstate freeways, as well as equally over all 24 hours of the day.

The first default input file that was modified to reflect the characteristics of the truck fleet resulting from the theoretical freight diversion was the distribution of vmt by vehicle class, which allocates the total vmt to each of 16 vehicle classes. The standard vehicle for this study, the diesel fueled combination tractor trailer truck with Gross Vehicle Weight Rating of 80,000 lbs, belongs to the heaviest MOBILE6 vehicle class, HDDV8B (Heavy Duty Diesel Vehicles with GVWR over 60,000 lbs). The vmt distribution groups diesel and gasoline vehicles together into the same weight class. Therefore 100% of the total vmt of the study's HDDV8B diversion trucks was allocated to HDV8B (Heavy Duty Vehicles with GVWR over 60,000 lbs). By comparison, the HDV8B is responsible for 4% of the total vmt in the default file used in run 1.

The second default input file that was modified to reflect the characteristics of the truck fleet resulting from the freight diversion was the distribution of vmt by facility. This distribution does distinguish between vehicles of the same weight class by fuel type. It distributes the vmt of each of the 28 vehicle classes, over each of the 24 hours of the day, as a percent vmt on each of four road types: freeways, arterials, local roads, and freeway ramps. The total percent vmt for each hour, for each vehicle class sums up to 100%. In general, the percent vmt allocated to each road type for a given class varies from hour to hour. However, an average percent vmt allocation over all 24 hours for HDDV8B in the default input file is 37% freeways, 48% arterials, 13% local roads, and 3% freeway ramps. In this study, long haul trucks carrying the diverted freight are assumed to travel primarily on interstates (freeway class), not on arterials, or local roads. Therefore, the vmt by facility for HDDV8B was modified to allocate 95% to freeways and 5% on freeway ramps. This allocation scheme was kept constant for each of the 24 hours because

long distance hauls have been shown to take place fairly evenly throughout the day and night. The default facility vmt distribution file reflects this fact based on national trends and data and shows that the percent of the hourly vmt over each type of facility for HDDV8B is fairly constant for each of the 24 hours of the day.

Table 7 shows the emission factors of the above pollutants, in grams per vmt, for HDDV8B resulting from both runs of MOBILE6. The diversion truck fleet, which is assumed to primarily operate on freeways (thus, at higher speeds), has a higher NO_x emission factor. EPA analyses[27] show that NO_x emissions of heavy diesel trucks increase exponentially with respect to speeds above 45 mph (usually occurring on freeways) or below 25 mph, approximately.

The output rates in grams per vmt, the vmt of the loaded trucks, and the diverted waterborne ton-miles led to the calculated emission rates in grams per ton-mile, also shown in the table. Every truck was assumed to return empty--or haul zero tons--so its return trip would have zero ton-miles. The conversion of vehicle-mile rates to ton-mile rates was necessary in order to enable a comparison with the water and rail modes on an equal basis. The reason is that the water and rail modes typically report and publish data using ton-miles, whereas highway data conventionally use vehicle-miles.

Also of note is that MOBILE6 outputs the fuel economy in miles per gallon (mpg) of each class of vehicles. For information purposes it is shown in the output table as well but it will be discussed in the next chapter, under energy efficiency.

Table 7. Emission Factors HDDV8B.

Run	Scenario	VOC	CO	NO_x	CO_2	PM-10	MPG
1	Default/Existing Trucks (g/vmt)	0.651	4.137	14.764	1,645.3	0.4523	6.2
2	Diversion Trucks (g/vmt)	0.504	3.408	18.301	1,645.1	0.4522	6.2
	Diversion Trucks (g/ton-mi)	0.020	0.136	0.732	65.8	0.018	--
Loaded truck vmt = 9,644 million Diversion Ton-miles = 241,108 million							

It is important to mention at this point that the HDDV8B emission factors resulting from the default run were somewhat higher than those for all classes of HDDV, since HDDV8B is the heaviest subclass and their emission factors are higher than the overall class average. The overall HDDV factors were compared with values seen in other federal sources, for example FHWA's Freight Facts and Figures[28], and found to be in agreement. This is not surprising since all federally published data are based on the same official sources of national estimates. For comparison purposes, these HDDV emission factors in grams per vmt are 0.54 for VOC, 3.05 for CO, and 11.45 for NO_x.

Although the range of increases in all pollutants is relatively modest, it must be borne in mind that this additional truck fleet will operate primarily in the vicinity of the waterways under study. The impacts will be more severe in this geographical area than locations far away from these

[27] U.S. Environmental Protection Agency. Office of Transportation and Air Quality. Sensitivity Analysis of MOBILE6.0. EPA420-R-02-035. December 2002.
[28] Federal Highway Administration. Freight Management and Operations. Freight Facts and Figures 2006. Table 5-11: Estimated National Average Vehicle Emissions Rates of Heavy- and Light- Duty Vehicles (grams per mile).

river bodies. The middle part of the U.S. already includes several areas designated by the EPA as Non-Attainment Areas, most commonly for ozone. The only Non-Attainment Area (for CO only) along the path of the Columbia/Snake Rivers is the area encompassing Portland, Oregon and Vancouver, Washington. Any emissions increase would only worsen existing problems. Figure 14 shows these non-attainment areas for Ozone and Carbon Monoxide along the inland waterways considered in this study.

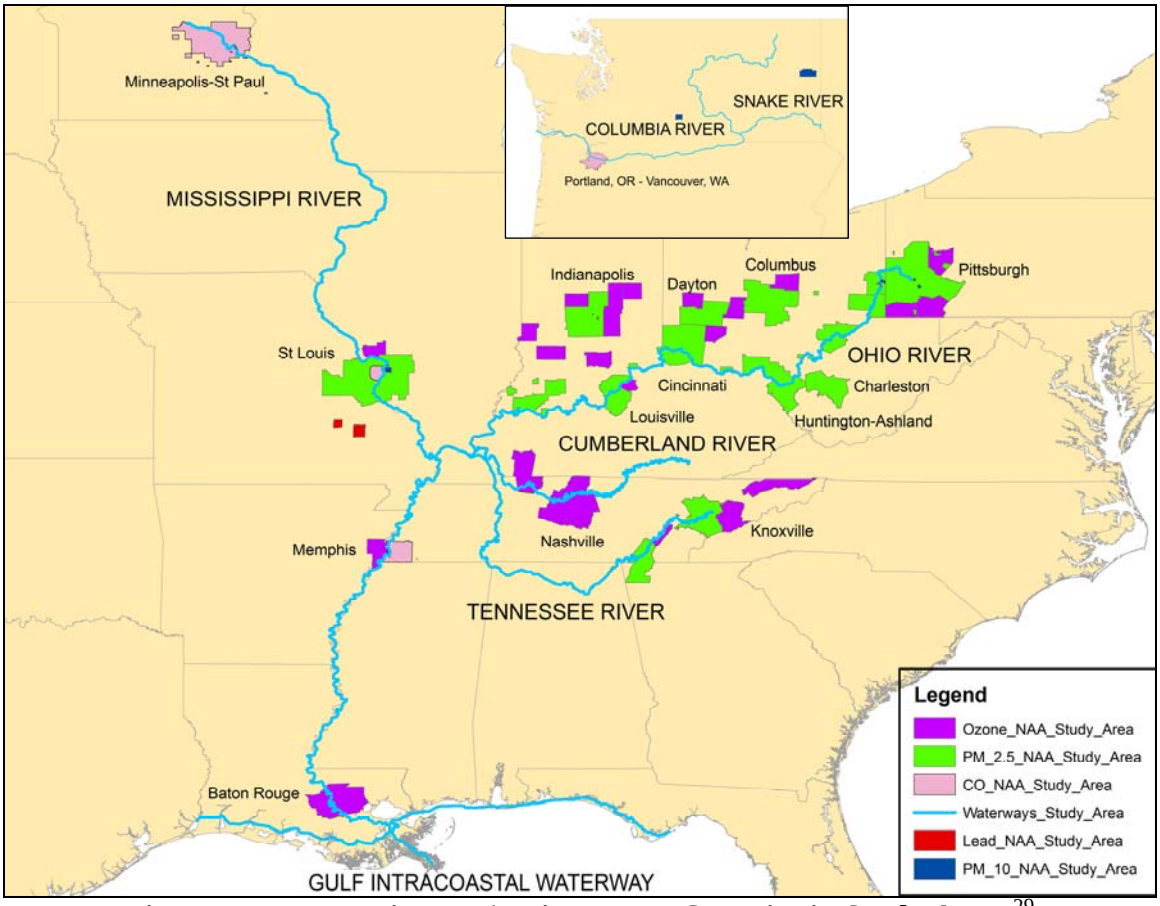

Figure 14. Nonattainment/Maintenance Counties in Study Area.[29]

Source: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics. National Transportation Atlas Databases

A theoretical waterborne freight diversion would have devastating effects on the entire spectrum of the trucking and fuel industries when new regulations and their implications are also considered. The demand for new trucks, drivers, and additional fuel supplies will increase dramatically. However, the potential air quality impact in future years is not quite as clear.

Future Federal Regulations – On-Road Vehicles

The EPA is establishing a comprehensive national control program that will regulate the heavy-duty vehicle and its fuel as a single system. As part of this program, new emission standards begin taking effect in model year 2007 and apply to heavy-duty highway engines and vehicles. These standards are based on the use of high-efficiency catalytic exhaust emission control

[29] U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics. National Transportation Atlas Databases 2007.

devices or comparably effective advanced technologies. Because these devices are damaged by sulfur, the EPA also reduced the level of sulfur in highway diesel fuel by 97% in mid-2006.

The EPA's PM emissions standard for new heavy-duty engines is set at 0.01 grams per brake-horsepower-hour (g/bhp-hr), and will take full effect for diesels in the 2007 model year. The standards for NO_x and non-methane hydrocarbons (NMHC) are 0.20 g/bhp-hr and 0.14 g/bhp-hr, respectively. These NO_x and NMHC standards will be phased in together between 2007 and 2010, for diesel engines. The phase-in will be on a percent-of-sales basis: 50% from 2007 to 2009 and 100% in 2010. Refiners were required to start producing diesel fuel for use in highway vehicles with a sulfur content of no more than 15 parts per million (ppm), beginning June 1, 2006. This study used 2005 data; hence MOBILE6 was run for calendar year 2005; therefore, the 2005 sulfur content of 500 ppm was input in the model.

The EPA estimates that the new standards will result in substantial benefits to the public health and welfare through significant annual reductions in emissions of NO_x, PM, NMHC, carbon monoxide, sulfur dioxide, and air toxics. According to the EPA, each new truck will be 90% cleaner than current models. EPA projects that the average price of $150,000 for a new heavy duty truck will increase by an average of $1,900. The cost of producing and distributing diesel fuel that is compliant with the new sulfur reduction requirement is estimated to increase by approximately five cents per gallon.[30] These estimates do not take into account the effect of the dramatic increase in demand for trucks and fuel that would occur if the traffic on the waterways were diverted to trucks.

RAILROAD LOCOMOTIVE AND MARINE EMISSIONS

The emissions from railroad locomotives have been regulated by the EPA since January 1, 2001.[31] During the period of this study's "snap shot in time" of 2005, the railroads were subject to two regulated levels of emissions. The locomotive emission levels are designated as Tier 0 and Tier 1 emissions.[32] The regulations establish emission standards as well as methods and procedures to calculate duty-cycle emissions from locomotives.[33] The EPA provides a conversion factor for the amount of pollutants locomotives would produce from each gallon of fuel used. The EPA also provides an estimated amount of emissions for each gallon of fuel consumed--270 grams of NO_x per gallon for line haul duty cycle locomotives.[34]

Conversion of Emission Factors to Grams per Gallon

It is often useful to express emission rates as grams of pollutant emitted per gallon of fuel consumed (g/gal). The EPA has developed a conversion factor to convert grams per brake-horsepower-hour (g/bhp-hr) to g/gal, and provides Table 8 for use in estimating emissions when fuel gallons are known. The railroad switch emission values are included in the table for

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[30] Environmental Protection Agency. Office of Transportation and Air Quality. Regulatory Announcement: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements. EPA420-F-00-057. December 2000. http://www.epa.gov/otaq/highway-diesel/regs/f00057.pdf.

[31] Title 40 CFR, 92, Subpart A, § 012.a, Tier 0 Standards.

[32] Federal Register / Vol. 63, No. 73 / Thursday, April 16, 1998 / Rules and Regulations, p. 18978, Summary.

[33] Title 40 CFR, 92, Subpart B, § 132, Calculations.

[34] EPA420-F-97-051, December 1997, Technical Highlights, Emission Factors for Locomotives, p. 2, accessible at http://www.epa.gov/otaq/regs/nonroad/locomotv/frm/42097051.pdf as of August 2007.

completeness, but are not used in reference to emissions from the railroads. The ton-miles due to rail yard switching are not included in EPA calculations or estimates. The railroads are required to provide kilowatt power production or fuel use in switchers for the estimate of emissions.

Table 8. Conversion Factors for Emissions in g/gal of Fuel Use.

Grams per Gallon Emission Factors (g/gal)				
	HC	**CO**	**NO_x**	**PM**
RR Line Haul	10	26.6	270	6.7
RR Switch	21	38.1	362	9.2

The EPA also promulgated Emission Standards for marine vessel engines. Before this regulation the commercial river boat marine engine emission was unregulated (prior to 2007). In 2005, the emission allowance was focused on NO_x emissions only. The amount of allowable emissions in 2005 was determined separately for idle conditions and running conditions. Essentially, the amount of emissions for 2005 is equivalent to uncontrolled locomotives. The idle emissions for marine vessels are difficult to evaluate since every engine will idle at a different speed. Since the amount of fuel used per ton-mile of revenue is estimated based on reported fuel tax collected by the Internal Revenue Service (IRS) and the tonnage reported to the U.S. Army Corps of Engineers, the idle and running emissions are not at issue in this analysis. The same issue is present for railroad emissions with a comparable solution. Because this analysis does not attempt to develop a route specific emission profile, the idle and running emission profiles are not necessary for this study.

GREENHOUSE GAS EMISSIONS

Table 13 in Chapter 5 provides a summary of fuel efficiency by mode. That table is reproduced below for easy reference.

Table 13. Summary of Fuel Efficiency.

Mode	Ton-Miles/Gallon
Inland Towing	576
Western Railroads	413
Eastern Railroads	413
Truck	155

The Environmental Protection Agency has published data on the fuel itself and the emissions that are created by burning the fuel. The GHG emission receiving the most focus around the world today is CO_2; therefore, this GHG analysis focuses strictly on CO_2. The relevant factors are summarized in the following table.

Table 9. EPA Greenhouse Gas Emissions Parameters--CO_2.

Diesel Fuel Carbon weight per US Gallon –	2,778 grams (average)/gal
% Carbon (C) oxidized into Carbon Dioxide (CO_2) -	99
CO_2 molecular weight (Carbon 12, Oxygen (16x2) 32) 12+32=44, or CO_2 multiplier is =	44/12
CO_2 weight is (2,778 x 0.99 x (44/12)) =	10,084 g/US gal
10,084 grams ÷ 453.59 grams per pound =	22.2 lbs/US gal

These calculations show that 2,778 grams of carbon/gal will oxide into 10,084 grams—or 22.2 lbs—of carbon dioxide.

Using the factors shown in Table 9, it can be shown that one ton of GHG is produced per 90.09 gallons of fuel consumed.

2,000 lbs/ton ÷ 22.2 lbs GHG/gal = 90.09 gal/ton GHG

Therefore, the values for the number of ton-miles delivered per ton of GHG produced will be 90 times the number of ton-miles per gallon of fuel used. The simplest way of expressing the differences in the modes is to calculate the amount ton-miles it takes for each mode to produce one ton of GHG. The following calculations take the ton-miles per gallon of fuel consumed by each mode and multiply by the gallons of fuel per ton of GHG. In other words, to produce a ton of GHG, a power unit must consume 90.09 gallons of fuel. Using trucks as an example, the 155 ton-miles per gallon of fuel associated with trucks must be multiplied by 90.09 to determine how many ton-miles can be produced before one ton of GHG is produced.

TRUCK

155 ton-miles/gal x 90.09 gal/ton-GHG = 13,964.0 ton-miles/ton-GHG

RAILROAD

413 ton-miles/gal x 90.09 gal/ton-GHG = 37,207.2 ton-miles/ton-GHG

INLAND TOWING

576 ton-miles/gal x 90.09 gal/ton-GHG = 51,891.8 ton-miles/ton-GHG

Graphically, this can be shown as follows.

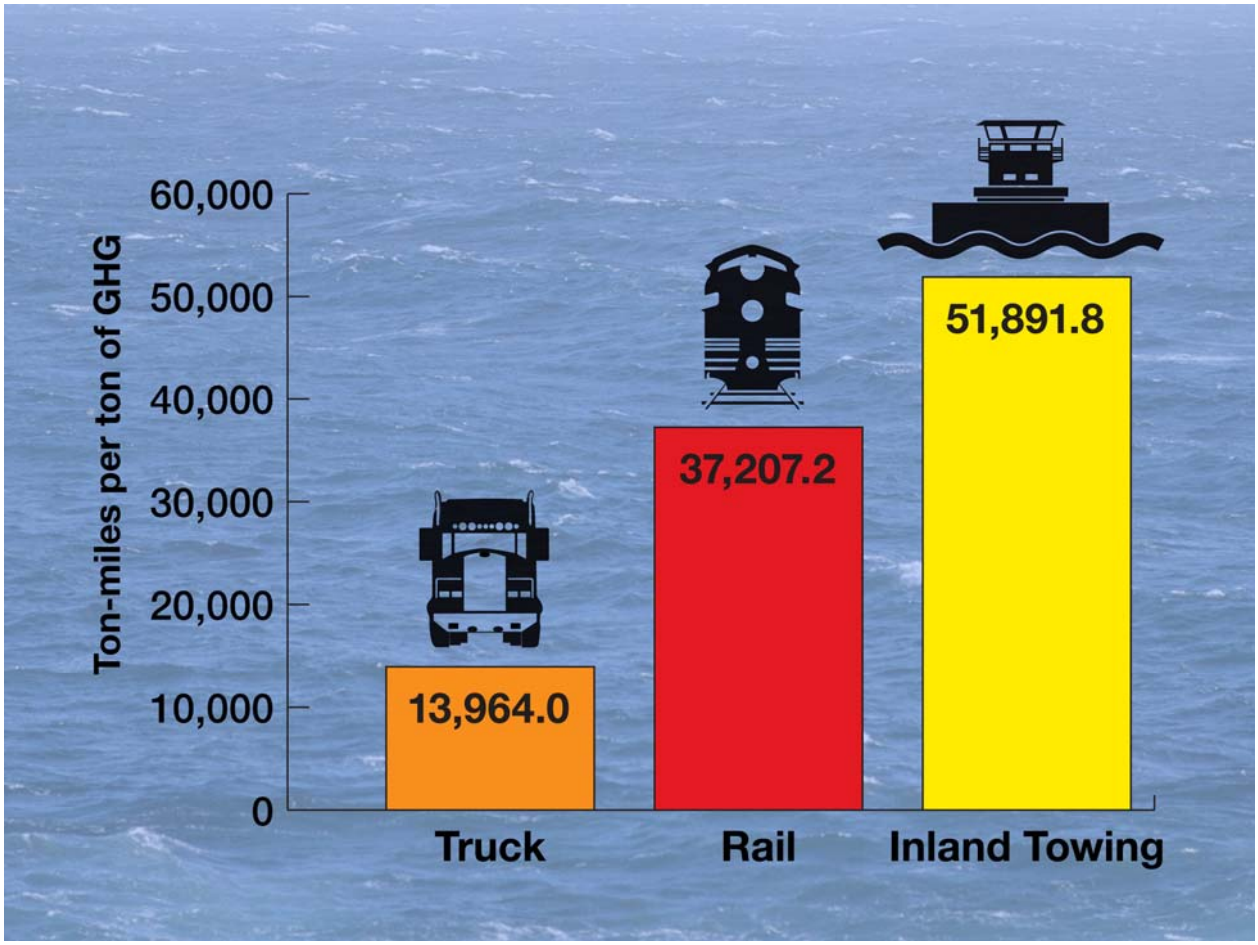

Figure 15. Ton-Miles per Ton of GHG.

Another way to evaluate the measure of the GHG between modes is to consider the tons of GHG per million ton-miles (tons-GHG/106 ton-miles). For each mode:

10^6 ton-Miles ÷ ton-miles/ton-GHG = ton-GHG/106 ton-Miles

TRUCK

10^6ton-Miles ÷ 13,964.0 ton-miles/ton-GHG = 71.61 ton-GHG/10^6 ton-Miles

RAILROAD

10^6ton-Miles ÷ 37,207.2 ton-miles/ton-GHG = 26.88 ton-GHG/10^6 ton-Miles

INLAND TOWING

10^6ton-Miles ÷ 51,891.8 ton-miles/ton-GHG = 19.27 ton-GHG/10^6 ton-Miles

These results are shown graphically in the following figure.

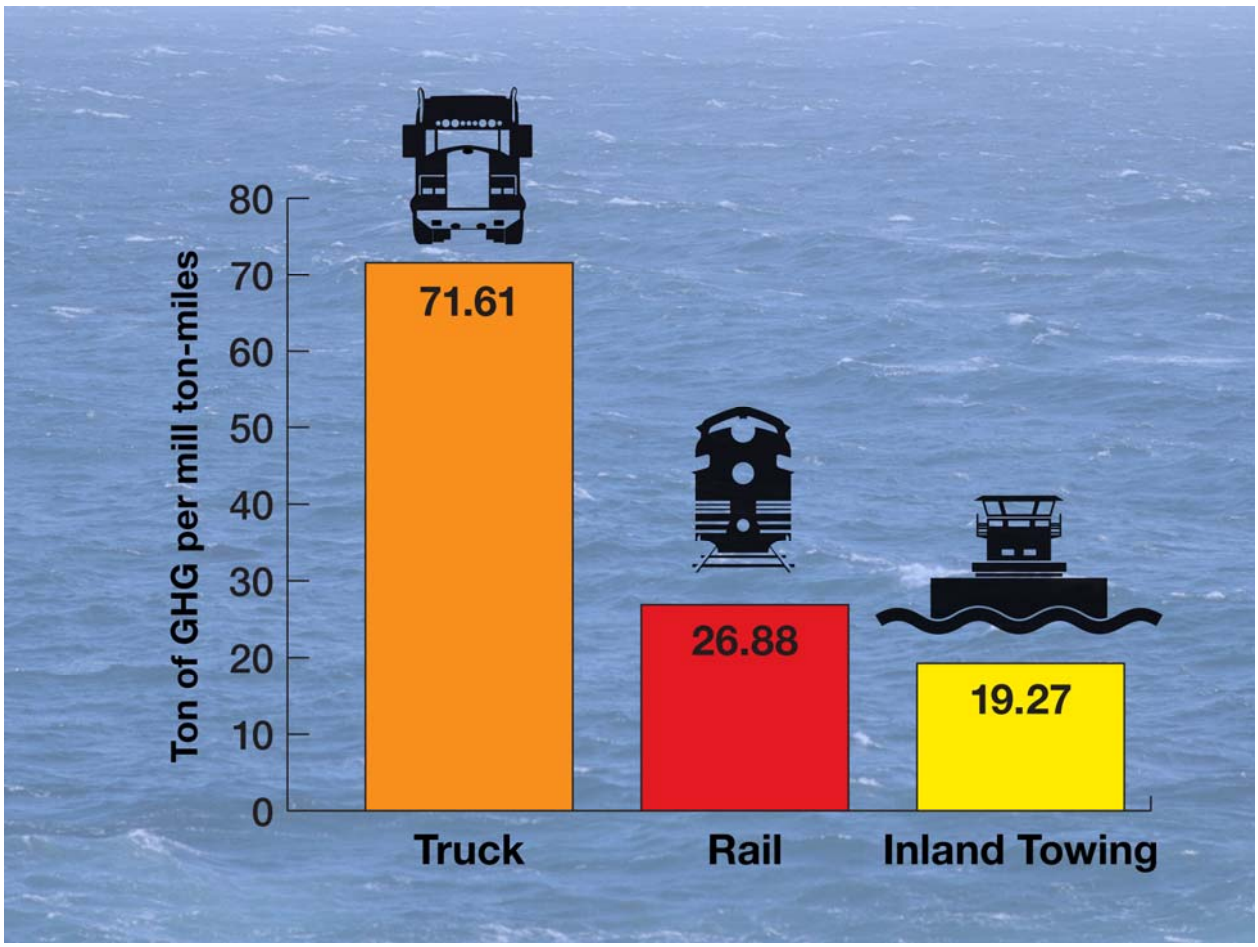

Figure 16. Tons of GHG per Million Ton-Miles.

According to statistics published by the U.S. Army Corps of Engineers, in 2005 (the original study year), the inland waterways logged 274.4 billion ton-miles of activity. Assuming that any modal change would result in the new mode operating at the average efficiency for the mode, the calculations above lead to the conclusion that had the inland waterway activity occurred on the railroads an additional 2.1 million tons of GHG would have been produced; on the highways an additional 14.4 million tons would have been emitted.

SUMMARY MODAL COMPARISON

The emission comparison between the three modes is shown in Table 10. The emissions for railroads are divided into East and West for the railroads but a single value supplied by the Tennessee Valley Authority (TVA) is used for marine emissions. The 2005 TVA value from Table 12 in the next chapter is used, 575.6 ton-miles per gallon of fuel. The average Eastern Railroad and average Western Railroad values from Table 11 (also in the next chapter) are used for the railroad emissions values.

Table 10. Summary of Emissions - Grams per Ton-Mile.

Emissions (grams/ton-mile)					
	HC	**CO**	**NO_x**	**PM**	**CO_2**[35]
Inland Towing	0.01737	0.04621	0.46907	0.01164	17.48
Eastern Railroad	0.02419	0.06434	0.65312	0.01624	24.39
Western Railroad	0.02423	0.06445	0.65423	0.01621	24.39
Truck	0.020	0.136	0.732	0.018	64.96

[35] CO_2 emissions for railroads were calculated on a system-wide basis.

CHAPTER 5: ENERGY EFFICIENCY

In the comparisons for the energy intensities of the freight modes evaluated in this study, energy used for moving the empty transportation equipment on return trips has been taken into account. The data for each freight transportation mode were examined to ensure that the empty movement portion was accounted for in the energy per revenue ton-mile calculations.

The MOBILE6 outputs include the fuel economy rate for HDDV8B in miles per gallon as estimated by the EPA, shown in the emissions impacts section to be 6.2 mpg, for both the existing truck fleet and the additional truck fleet that would be transporting the waterborne freight under a diversion scenario. This figure fares well in comparison with FHWA's published average fuel consumption of combination trucks of 5.9 mpg in 2004, which is the latest data year in the respective table in Freight Facts and Figures 2006[36]. Conventionally, vehicle-miles traveled are used in reporting and publishing data for the highway mode, whereas ton-miles are used for the water and rail modes. For this reason, comparison of the highway mode to the other two modes in this study, warranted conversion of vehicle-mile rates to ton-mile rates.

When the truck fuel efficiency rate of 6.2 miles per gallon is multiplied by the assumed truckload of 25 tons of cargo, a truck fuel efficiency of 155 ton-miles per gallon is generated. Each return trip is assumed to be empty – or haul zero cargo tons. The fuel efficiency of the return trip in ton-miles per gallon mathematically would equal zero, but the fuel efficiency in vehicle-miles per gallon would still equal 6.2. Since an across the board comparison of the three modes requires the use of a ton-miles per gallon rate, 155 ton-miles per gallon is the proper figure to use, which describes the fuel efficiency of a loaded truck.

A comparison of energy consumption for freight movement by the various surface transportation modes has previously been attempted. The researchers investigated the possible use of such a comparison contained in the U.S. Transportation Energy Data Book[37], but determined that the methodology used was not appropriate. For this report, the researchers calculated energy efficiencies using detailed data supplied by each transportation industry sector to government regulatory entities.

For freight modes, a significant portion of the energy expended is attributed to non-haul purposes. For example, almost half of the energy consumed by freight rail is not used to move freight:

- More than 30% is used for empty backhaul.
- About 4% is reported lost or spilled each year.
- About 4% is consumed in idling.
- 10% is used by yard locomotives assembling and switching cars.[38]

[36] Federal Highway Administration. Freight Management and Operations. Freight Facts and Figures 2006. Table 5-9: Combination Truck Fuel Consumption and Travel.
[37] U.S. Department of Energy. Oak Ridge National Laboratory. Davis, S.C. and Diegel, S.W. Transportation Energy Data Book: Edition 26. ORNL-6978. 2007.
[38] A.B. Rose, Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movements, ORNL-5554 (Oak Ridge, TN: Oak Ridge National Laboratory, June 1979), pp. S-10 and 5-4.

The energy consumption in the railroad industry was carefully evaluated in order to ensure that the full energy as well as the total equipment and freight mileage movements were included. The data for the railroads were spread among four primary sources: the Association of American Railroads (AAR), the Surface Transportation Board (STB), Security and Exchange Commission (SEC), and the railroads' own annual reports to stockholders.

The AAR data were found on the AAR website in the RR Industry Info, Statistics, and Performance Measures sections. Both the SEC and the STB websites provide each railroad's required federal filings. The SEC data source is the 10-K annual report of financial status and operating data. The STB provides each railroad's R-1 report that includes operating data, particularly the railroad's locomotive fuel dollars on Schedule 410, line 409, and the gross ton-miles of traffic reported on Schedule 755, line 104. The individual railroad's average annual cost per gallon of fuel is discretionarily available in their individual annual report. Additionally, individual railroads may include the actual gallons of locomotive fuel consumed in their annual report; however this value is not consistently reported by any of the railroads.

Table 11 lists the fuel efficiency calculated by the researchers using the available data from sources described above and the AAR reported value for gross ton-miles per gallon of fuel for the year 2005 as provided in the RR Statistics document on their website.

Table 11. Calculated Railroad Fuel Efficiency.

	Gross Revenue Ton-Miles ($x10^6$)[39]	Fuel Consumed ($x10^6$)[40]	Ton-Miles/Gallon[41]
AAR			414
BNSF	594,676	1,402.3	424
CN	54,064	110.7	488
CPR	23,595	49.3	478
CSX	247,411	595.5	415
KCS	25,167	74.0	340
NS	202,751	513.4	395
UP	548.761	1,362.9	403
Average All Roads	1,696,425	4,108.1	412.9
Average West Roads	1,192,199	2,888.5	412.7
Average East Roads	504,226	1,219.6	413.4

It is more difficult to develop energy consumption data for the inland waterways (river and Gulf Intracoastal Waterways) operators than for the railroad industry. The marine industry only

[39] STB R-1 Annual Report, Schedule 755, Line 110: Total Gross revenue ton-miles all trains.
[40] STB R-1 Annual Report, Schedule 750, Line 4: Total Fuel Consumed all trains except passenger.
[41] Calculated value, Gross Revenue Ton-Miles divided by Fuel Consumed.

reports tax information on fuel purchases to the federal government. Access to detailed information on individual moves is restricted and is generally available only to the Corps. The Corps has contracted with the Tennessee Valley Authority (TVA) to develop software to model the fuel consumption, reported tonnages, and traffic mileage of marine freight transportation for the waterways for which the Corps has jurisdictional responsibility.

TVA provided the modeled data for the marine ton-miles per gallon of fuel for the years 2003, 2004, and 2005. The model has been repeatedly tested by the TVA against the U.S. IRS tax data for fuel tax collected on various sections of the U.S. river system in order to verify its validity. The model has been verified to be consistently accurate within 0.3% of the actual reported tonnage and fuel tax collected in the validation tests. Table 12 lists the TVA modeled fuel efficiency for the marine industry for the river navigation system.[42]

Table 12. Marine Fuel Efficiency.

TVA Fuel Efficiency Model - Ton-Mile Values	
Year	**Ton-Miles/Gallon**
2003	574.1
2004	575.7
2005	575.6

Source: Tennessee Valley Authority

The railroads are 28.3% less fuel efficient than the inland waterway freight transportation system based on revenue ton-miles per gallon. This difference could possibly increase in future years. The increased demand for freight transportation on the rivers has caused a waiting queue to develop at the locks on the rivers. Where shorter locks (less than 1200 feet) are located, more tows must be broken up and moved through in multiple lockages. This causes a significant amount of fuel usage by the towboats to maintain steerage control during the wait period. Improving the locks could make a significant difference in fuel consumption. Additionally, the railroads have been subject to new regulation by the EPA to reduce locomotive emissions. This impetus has forced the manufacturers of locomotives to provide lower emission engines. One way the locomotive engine manufacturers found to lower emissions was to increase engine efficiency by reducing fuel consumption. Reducing locomotive fuel consumption while maintaining power requirements has increased railroad ton-mile efficiency. Marine engine emission regulations have not yet been finalized, although the industry is already moving to more fuel-efficient engines for economic reasons. Once the marine industry is required by regulation to reduce emissions, the towboat fuel consumption will follow the logical path already explored by the railroad industry.

[42] Data provided by Chrisman A. Dager, Transportation Economist, Tennessee Valley Authority.

Table 13 and Figure 17 present the results of the fuel efficiency calculations on a national industry-wide basis in summary form.

Table 13. Summary of Fuel Efficiency.

Mode	Ton-Miles/Gallon
Inland Towing	576
Western Railroads	413
Eastern Railroads	413
Truck	155

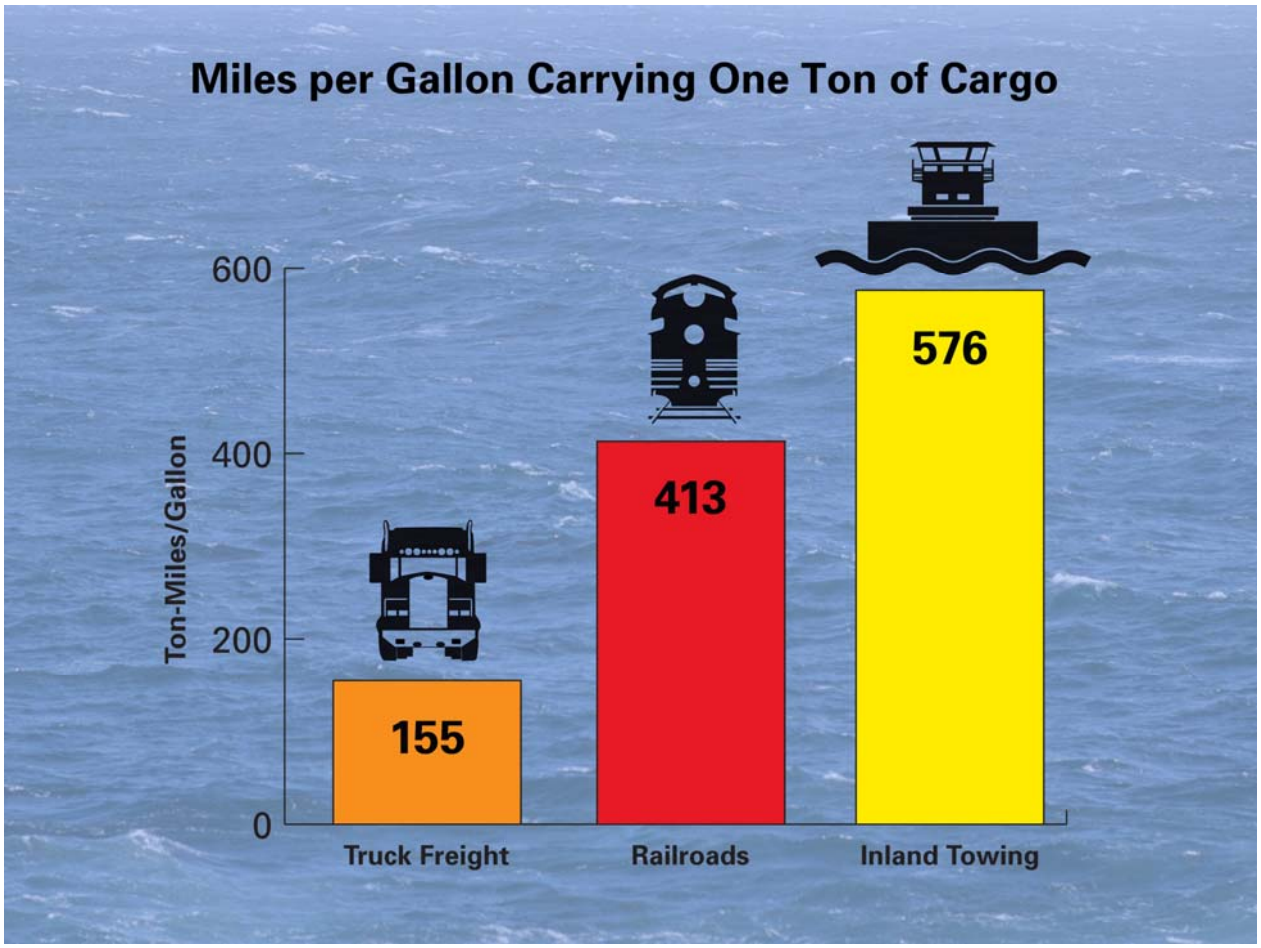

Figure 17. Comparison of Fuel Efficiency.

CHAPTER 6: SAFETY IMPACTS

This study evaluates the impacts resulting from diversion of barge freight to the highway or rail mode using three primary types of safety measures: fatalities, injuries, and hazardous materials spills.

FATALITIES AND INJURIES

The data for rail fatalities and injuries respectively were obtained from *Railroad Statistics: National Transportation Statistics - 2006, Table 2-35: Railroad and Grade-Crossing Fatalities by Victim Class* and *National Transportation Statistics - 2006, Table 2-36: Railroad and Grade-Crossing Injured Persons by Victim Class.* Data for truck-related incidents were obtained from *Large Truck Crash Facts, 2005*, a publication of the Federal Motor Carrier Safety Administration. The data for waterborne incidents were taken from the *Marine Casualty and Pollution Database, July 2006*, a database that is maintained by the U.S. Coast Guard. The marine casualty database includes all incidents that occurred in water, whether deep-sea or inland; therefore, the dataset was reduced to only those incidents involving river barge traffic in order to facilitate further analysis.

Both rail and truck statistics include incidents involving only vehicular crashes or derailments. However, the waterborne database reports incidents resulting from a wide variety of causes. In order to conduct a valid modal comparison for this study, a definition of "incident" analogous to the one used in the surface mode data was adopted. Data pertaining only to waterborne incidents involving collisions, allisions (vessels striking a fixed object), or capsizings were further extracted and used in analysis.

The statistics for each mode were converted to a rate per million or billion ton-miles to facilitate comparison. Four sources were used for ton-mile data: *National Transportation Statistics - 2006, Table 1-46a: U.S. Ton-Miles of Freight (Millions); National Transportation Statistics - 2006, Table 1-46b, Special Tabulation (highway data); Association of American Railroads Website (2005 ton-miles); Waterborne Commerce Statistics, 2005.*

The comparison of fatality rates is shown in Table 14 and Figure 18. Figure 16 shows the ratio of rail to water and truck to water; it is simply each mode's rate per billion ton-miles divided by the inland waterway rate per billion ton-miles.

Table 14. Fatality Statistics by Mode.

Mode	4-yr avg ton-miles (millions)	4-yr avg fatalities (operator)	Rate per Billion ton-miles	4-yr avg fatalities (other)	Rate per Billion ton-miles	4-yr avg total fatalities	Rate per Billion ton-miles
Highway	1,259,535	722	0.573227	4,758	3.777585	**5,480**	**4.351**
Railroad	1,554,130	28	0.018017	884	0.568807	**1,008**	**0.649**
Inland Towing	287,680	1	0.003476	7	0.024333	**8**	**0.028**

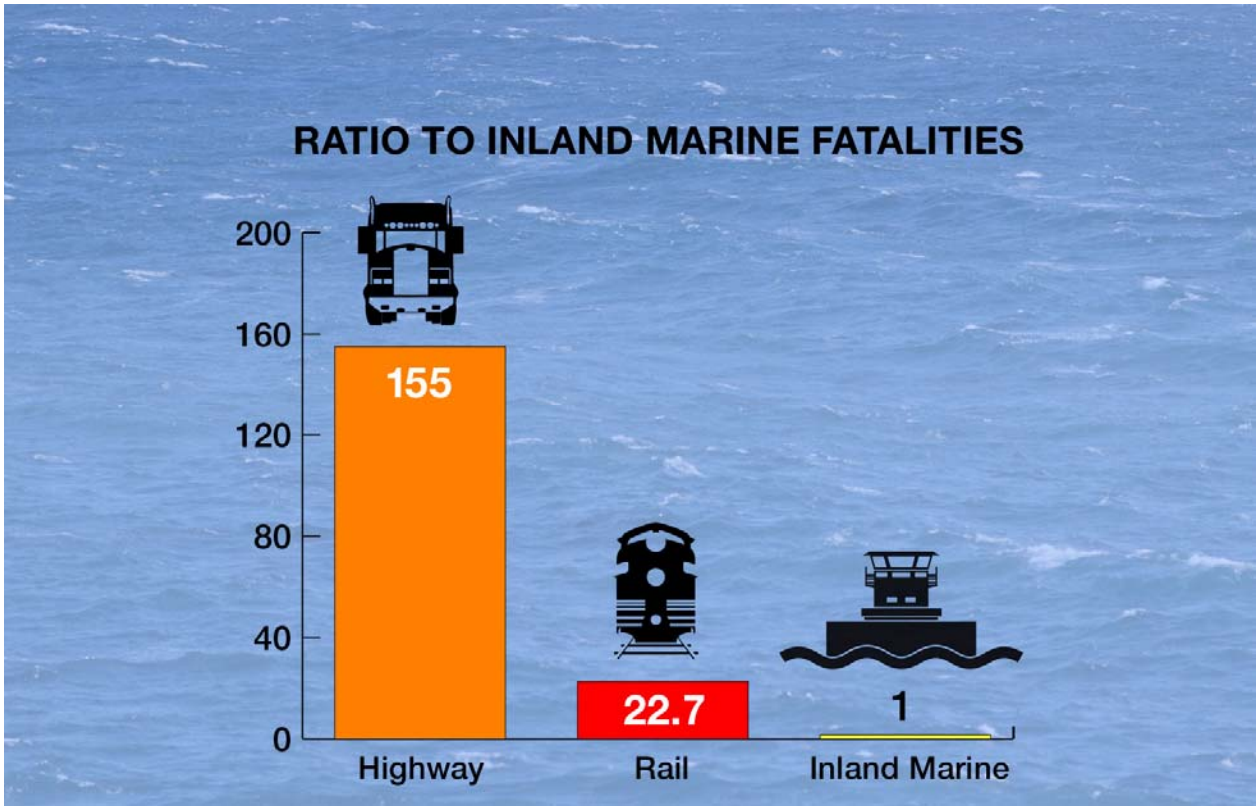

Figure 18. Ratio of Fatalities per Bill Ton-Miles Versus Inland Marine.

In the case of fatalities it is possible to distinguish between injuries to operators of the modal equipment and injuries to other individuals. In the case of injuries, the data are not sufficiently detailed for trucks to allow a comparison; therefore, all injuries are lumped together, as shown in Table 15 and Figure 19. Figure 17 is similar to Figure 16. It shows the ratio of rail to water and truck to water; it is simply each mode's rate per billion ton-miles divided by the inland waterway rate per billion ton-miles.

Table 15. Comparison of Injuries by Mode.

Mode	4-yr avg ton-miles (millions)	4-yr avg total injuries	Rate per Billion ton-miles
Highway	1,259,535	**124,750**	**99.044**
Railroad	1,554,130	**9,036**	**5.814**
Inland Towing	287,680	**13**	**0.045**

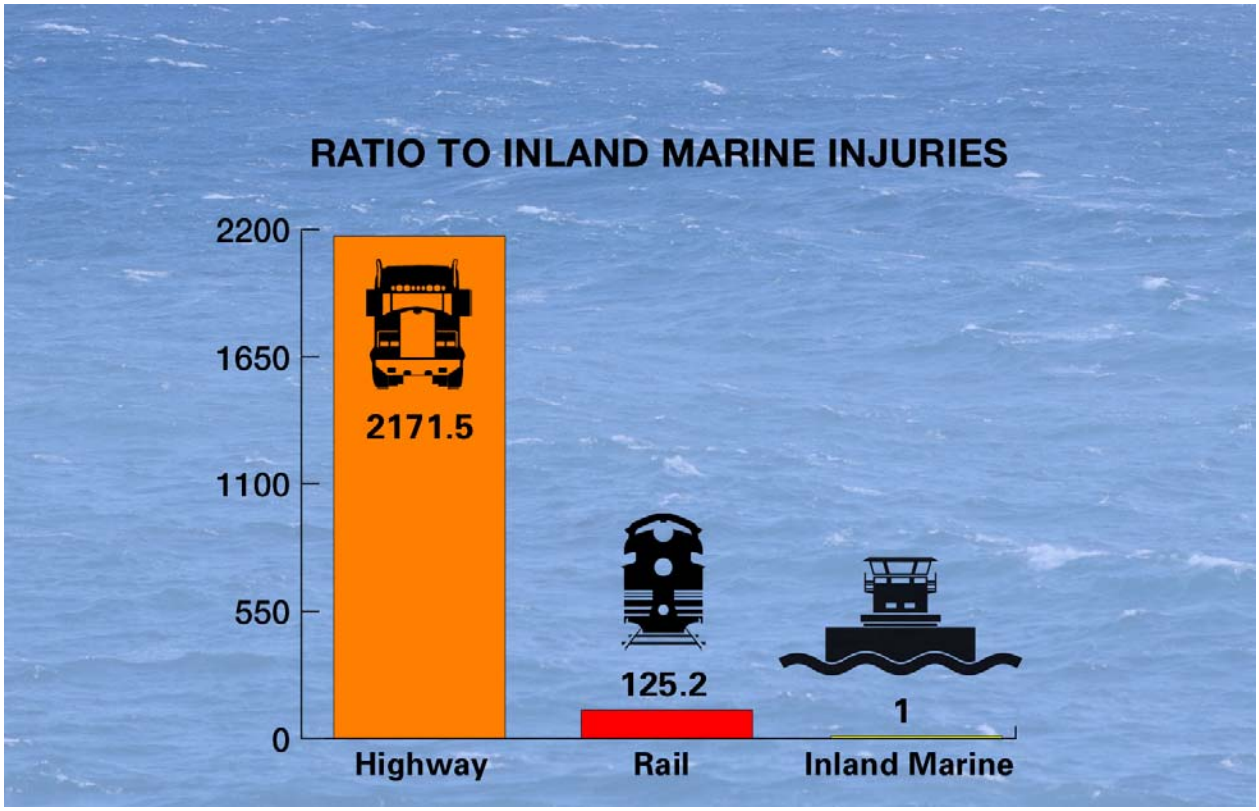

Figure 19. Ratio of Injuries per Bill Ton-Miles Versus Inland Marine.

HAZARDOUS MATERIALS INCIDENTS

Hazardous materials incidents are reported differently across the modes. Incidents for all three modes are contained in the Pipeline and Hazardous Materials Safety Administration's *Hazardous Materials Incident Reporting System, 2001-2005*. However, a close examination of the incidents for marine transportation revealed that only deep-sea incidents are being stored in the system; therefore, it was necessary to acquire data from the Coast Guard and from the Corps of Engineers regarding IWWS-related traffic.

The Coast Guard stores information on all incidents involving marine transportation while the Corps of Engineers reports tonnage and ton-mile statistics. The Corps reports the commodities

according to Standard International Trade Classification (SITC) code, a statistical classification system designed by the United Nations for commodities in international trade to provide the commodity aggregates needed for purposes of economic analysis and to facilitate the international comparison of trade-by-commodity data. The data reported by the Pipeline and Hazardous Materials Safety Administration (PHMSA) use United Nations UN Identification Numbers for tracking commodities. Since the objective of this analysis is to develop an incident rate (as opposed to a comparison of how much of a given product is spilled), the PHMSA spill and ton-mile data are used for truck and rail statistics, while the Coast Guard and Corps data are used for the waterborne activity.

The Coast Guard transitioned to a new marine casualty tracking system in late 2001. Prior reviews have indicated that some of the data from 2001 were not picked up in the newer system. Since this report covers 2001-2004, it was necessary to review the data for both systems for 2001, while the newer system was used exclusively for 2002-2004. The earlier system was known as the Marine Safety Information System (MSIS). The current system is referred to as the Marine Information for Safety and Law Enforcement (MISLE) system. The Coast Guard data do not segregate deep-sea incidents from IWWS incidents, so the research team extracted the spills related to IWWS traffic. Then the team coded the commodities that were spilled according to the SITC scheme. Only SITC codes that coincide with the Corps' statistics on Haz-Mat traffic were retained. This allows a valid calculation of the rate of spills versus the ton-miles of material that were transported.

Due to the fact that all three reporting systems basically rely on self-reporting, and the definitions of materials that require reporting are very complex, much of the spill data are suspect. However, for larger spills, it seems reasonable to assume that the accuracy of the data improves, due to the severity of the incident and public scrutiny; therefore, the research team decided to analyze only large spills as a measure of the overall safety of the modes in the area of spills. The threshold quantity was set at 1,000 gallons.

Table 16 and Figure 20 provide a comparison of spills across the modes:

Table 16. Comparison of Large Spills Across Modes.

	Totals		4-Year Averages (2001-2004)					Rates	
	Number of Spills	Amt in Gallons	Number of Spills	Amt in Gallons	Average Ton-Miles (millions)	Percent Haz-Mat	Haz-Mat Ton-Miles (millions)	Spills/B Ton-Mile	Gal/M Ton-Mile
Truck	643	2,698,490	161	674,622	1,259,535	8.84%	111,404	1,442,942	6.06
Rail	115	1,147,105	29	286,776	1,554,130	4.78%	74,341	386.729	3.86
Inland Towing	25	470,579	6	117,645	287,680	11.36%	32,668	191.319	3.60

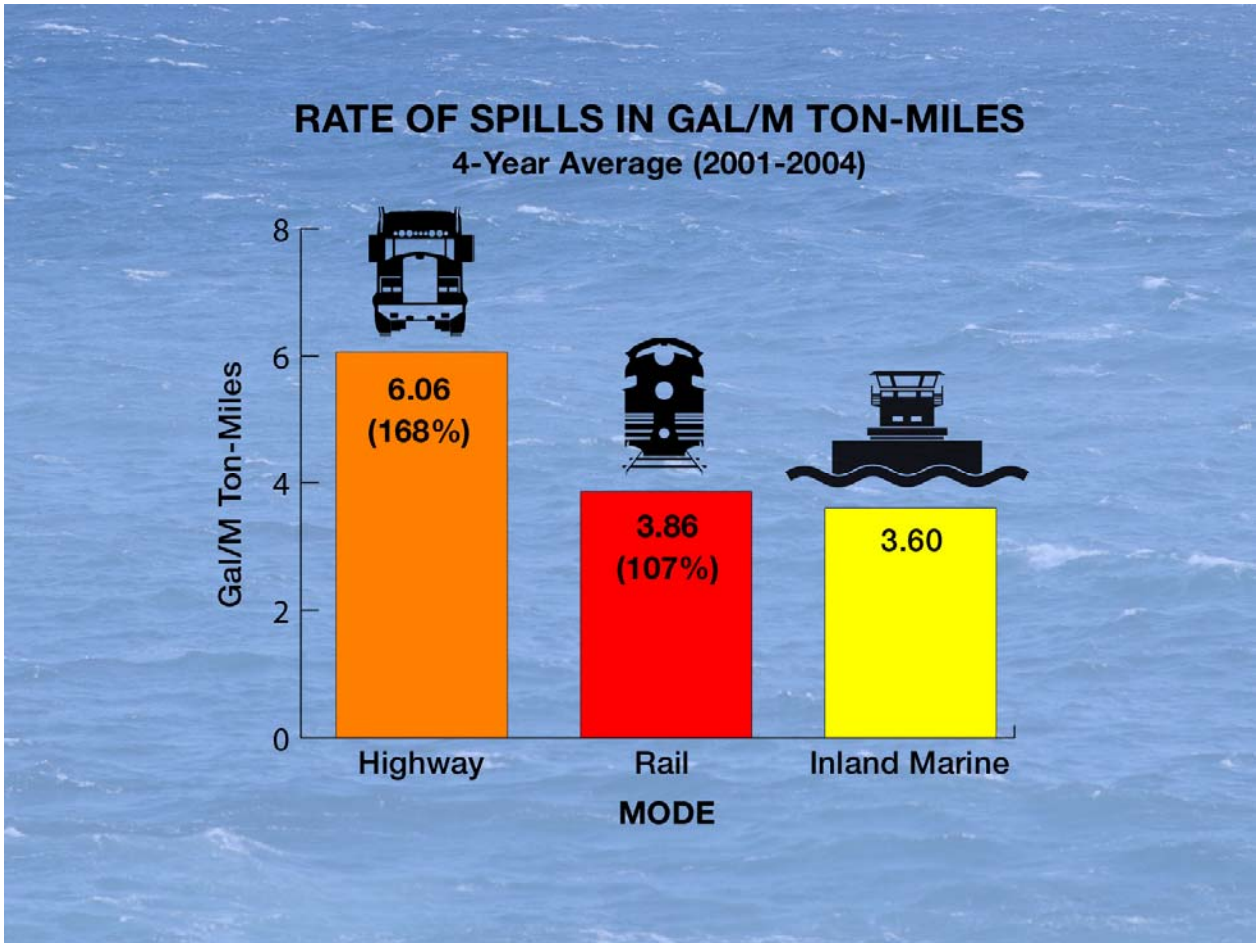

Figure 20. Ratio of Large Spills per Mill Ton-Miles Versus Inland Marine.

Large spills (≥1,000 gal) are 97% of the total volume for waterborne traffic, 96% for rail, and 85% for trucks. What the statistics do not show (and this project does not attempt to analyze) is the effect such incidents have on the human population. Because they use infrastructure shared with the general public—infrastructure which has a high utilization rate by the general public—spills from truck and rail incidents almost always pose an immediate threat to the health of human beings. Waterborne transportation, by virtue of the fact that it occurs on a river, rarely poses an immediate threat to human beings, although it may have a detrimental effect on aquatic flora and fauna.

The project team attempted to compare damages from hazardous materials incidents, but the data are extremely unreliable, so this analysis was not performed.

CHAPTER 7: INFRASTRUCTURE IMPACTS

The question addressed in this part of the analysis is, "What are the potential impacts to rail and highway infrastructure caused by a hypothetical diversion of waterborne traffic to either mode?"

In order to analyze the advantages of waterborne over surface transportation with respect to infrastructure, the effects of a situation where the waterways are closed and all cargo is forced to move either by rail or truck are evaluated. It is a highly unlikely event, but such an analysis helps emphasize the savings to the nation due to the utilization of waterborne transportation.

PAVEMENT DETERIORATION

Roadway pavements need to be designed at a level of structural capacity that can withstand the repeated loadings inflicted by heavy trucks. Passenger cars inflict minimal damage to the pavement by comparison. Pavement structural capacity is measured by the Structural Number (SN) and new pavements – which are at "full strength"- have a SN of 4.5-5.0. The useful life of a new pavement is approximately 20 years, at which point the SN drops to about 2.5 and major rehabilitation is required. The total load expected over the pavement's "lifetime" due to heavy truck traffic is the primary input in calculating the thickness of a new pavement.

Previous chapters have defined the "standard" truck to be used in the event of a waterborne freight diversion as the combination tractor-semitrailer truck with GVWR of 80,000 lbs. Figure 21 shows the axle configuration of this type of truck. There are five axles total, one steering axle, and four remaining axles in pairs, called "tandem axles".

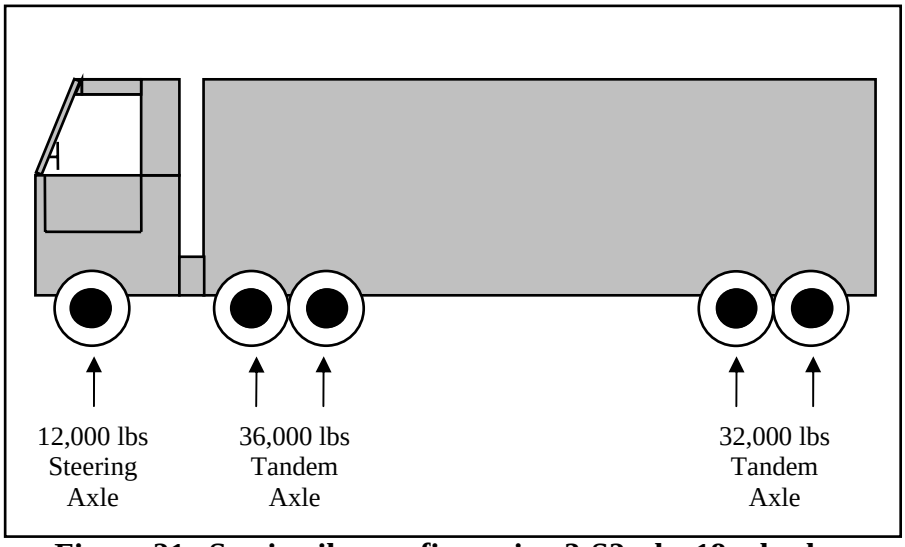

Figure 21. Semitrailer configuration 3-S2: the 18-wheeler.

Tandem axles are closer together and inflict less pavement damage than two single axles further apart. The integrated load a truck exerts on a pavement is estimated by the number of Equivalent 18,000-pound (or 18-kip) Single Axle Loads or ESAL using the Association of State Highway and Transportation Officials (AASHTO) "fourth power" equation. The two equations for

calculating the ESAL on a flexible (asphalt) pavement due to the weight on a single axle (W_{Single}) and due to the weight on a tandem axle (W_{Tandem}) respectively are:

$$ESAL_{Single} = \left(\frac{W_{Single}}{18{,}000lbs}\right)^4 \qquad ESAL_{Tandem} = \left(\frac{W_{Tandem}}{33{,}200lbs}\right)^4$$

The standard 18-wheeler has one 12,000 lb steering axle, a 36,000 lb tandem axle, and a 32,000 lb tandem axle, so the ESAL it exerts on the asphalt pavement is 2.44 ESAL, as shown below:

$$ESAL_{18-Wheeler} = \left(\frac{12{,}000}{18{,}000}\right)^4 + \left(\frac{36{,}000}{33{,}200}\right)^4 + \left(\frac{32{,}000}{33{,}200}\right)^4 = 2.44$$

In 2003 there were 5,465 Average Daily Vehicles per Lane on Rural Interstates. Highway Statistics[43] reports that, in the same year on rural interstates, 16% of the traffic – or 874 vehicles - were combination trucks, or 18-wheelers. Assuming that no waterborne freight diversion will occur, the annual ESAL would be:

$$ESAL_{Annual} = 2.44 \times 874 \times 365 = 0.78 million$$

The analysis for congestion impacts estimates that a diversion of waterborne freight to the highway mode would result in a total of 2,034 combination trucks per day per lane of a typical rural interstate, thus the annual ESAL would be:

$$ESAL_{Annual} = 2.44 \times 2{,}034 \times 365 = 1.8 million$$

Since the total loadings over the pavement lifetime are to be considered in designing a new pavement, the expected growth in truck traffic over the same period has to be included. At an annual constant percentage growth, *g*, of 2% and a pavement design lifetime, *N*, of 20 years, the ESAL expected assuming continuation of current conditions would be:

$$ESAL_{Expected} = ESAL_{Annual} \times \frac{(1+g)^N - 1}{g} = 0.78 million \times \frac{(1+.02)^{20} - 1}{0.02} = 18.9 million$$

Similarly, assuming a waterborne freight diversion occurs, the ESAL expected over a 20-year pavement life would be:

$$ESAL_{Expected} = ESAL_{Annual} \times \frac{(1+g)^N - 1}{g} = 1.8 million \times \frac{(1+.02)^{20} - 1}{0.02} = 44.1 million$$

[43] Federal Highway Administration. Highway Statistics 2005. Section V: Roadway Extent, Characteristics, and Performance. Percentage Distribution of Traffic Volumes and Loadings on the Interstate System, Table TC-3.

A quick comparison of the two calculated values indicates that if a waterborne freight diversion occurs, the ESAL expected over the pavement throughout its 20-year lifetime is more than double (233%) the ESAL expected under current conditions.

The AASHTO guidelines for pavement design[44] were then followed to determine the pavement thickness required to accommodate the ESAL expected over the pavement's lifetime, first, assuming continuation of current conditions, and second, that a waterborne freight diversion will occur. Identical values for these remaining required parameters were used to ensure comparison on an equal basis:

- Reliability, R: 90%
- Standard Deviation S_o: 0.35
- Serviceability Loss, Δ PSI: 2.0
- Subgrade Strength, M_R: 10,000 psi
- Asphalt Concrete Elastic Modulus, E_{AC}: 380,000 psi
- Asphalt Concrete Surface Course Structural Layer Coefficient, a: 0.41

At the current level of ESAL expected over the pavement throughout the 20 years, the design Structural Number, SN, was found to be 4.6, which is within the range of an SN of 4.5 to 5.0 for a new pavement or a pavement at full strength - one that has undergone major rehabilitation, typically 20 years after construction. In order for clearer comparison to take place, an all-asphalt pavement is assumed, whose required thickness, *d*, in inches, is:

$$d = \frac{SN}{a} \qquad \text{Here,} \quad d = \frac{SN}{a} = \frac{4.6}{0.41} = 11.2\ inches$$

At the level of ESAL assuming freight diversion, the design Structural Number, SN, was found to be 5.3, which is natural since a higher ESAL is expected over the pavement's lifetime. Similarly, in order for clearer comparison to take place, an all-asphalt pavement is assumed, whose required thickness, *d*, in inches, is:

$$d = \frac{SN}{a} \qquad \text{Here,} \quad d = \frac{SN}{a} = \frac{5.3}{0.41} = 12.9\ inches$$

Comparison of the thickness results implies that in the event of a waterborne freight diversion, a flexible pavement on an average rural interstate would require an additional 1.7 inches of asphalt layer in order to adequately withstand the 20-year loadings of combination trucks without requiring premature major rehabilitation (before the 20 years expire). The asphalt thickness addition would occur at the construction stage of a new pavement or as an overlay to an existing pavement so that the pavement strength rises to the required SN of 5.3 and its longevity for the next 20 years is ensured, at which point major rehabilitation will have to be undertaken. Of course if the existing pavement is already worn, the asphalt layer thickness will have to be first brought up to the 11.2 inches, and then up to the 12.9 inches so that it is strong enough to last for the next 20 years.

[44] American Association of State Highway Transportation Officials. Guide for Design of Pavement Structures 1993 and 1998 Supplement.

In the field, the additional 1.7 inches of asphalt layer calculated above would be rounded to 2 inches, which is also the minimum asphalt overlay thickness typically performed by departments of transportation. Assuming an even truck traffic distribution, a minimum 2 inches thickness of asphalt layer would have to be added to the pavement of 126,000 lane-miles of rural interstate given the higher levels of expected 20-year truck loadings.

Assuming an even truck traffic distribution, a minimum 2 inch thickness of asphalt layer would have to be added to the pavement of 126,000 lane-miles of rural interstate given the higher levels of expected 20-year truck loadings.

Further Highway Infrastructure Impacts

The system wide impacts to infrastructure can be put into perspective when it is borne in mind that the rural segments of the interstate system consist of 126,000 lane-miles[45]. In addition, there are 86,000 lane-miles of urban interstate, 350,000 lane-miles of other classes of National Highway System roadways, and 1.8 million lane-miles of other federal-aid highways.

Corridors that are parallel to the major rivers considered would undoubtedly receive a higher concentration of the additional truck traffic, and would be impacted at a higher degree than the national average. This analysis assumed that truck traffic would be equally distributed over all lanes, but in reality this may not be always true. In rural road segments with a low density of entry and exit ramps the outer lane is used by trucks more heavily and the pavement in that lane sustains considerably higher levels of damage than the inner lane.

Higher levels of heavy truck traffic typically require significant capital expenditure on bridges, ramps, highway geometric features such as horizontal and vertical curves and shoulders, truck stops, weigh stations, signage, etc., as well as higher routine maintenance costs.

It is beyond the scope of this analysis to accurately predict, analyze, or associate any monetary cost with other possible infrastructure impacts or improvements that would be required in the event of a waterborne freight diversion to heavy trucks. However, a transportation engineer can safely rely on past trends and experience to argue that these would include improvements in the form of capital expenditures on new construction of infrastructure and facilities such as bridges, ramps, highway geometric features such as horizontal and vertical curves and shoulders, truck stops, service stations, rest areas, weigh stations, and signage. In addition, routine maintenance costs associated with the new infrastructure as well as with the existing, which would be used more heavily, would likely be significantly higher.

RAILROAD INFRASTRUCTURE IMPACTS

The shift of the inland waterways freight to the existing railroads would impact the individual railroads at substantially different levels. Although a detailed economic analysis of costs to the railroads of the modal shift of all the inland waterway freight is beyond the scope of this analysis, a closer look at the previous rail impact example discussed in Chapter 3 can provide

[45] Federal Highway Administration. Highway Statistics 2005. Section V: Roadway Extent, Characteristics, and Performance. Federal Aid Highway Lane Length, Lane-Miles by System. Table HM-48. October 2006.

further indication of what the railroads could be expected to encounter with the possible closure of individual water transportation segments or entire routes.

CSX currently delivers coal to electric generating plants located along or in the near vicinity of the Ohio River. Consequently, the CSX Ohio River route track has some amount of dedicated coal train traffic. (See Figure 22.) If, in the example of the Ohio River closure, the CSX railroad were tasked with the transportation of the entire coal tonnage of the river, the probable initial outcome would be electric brownouts and interrupted manufacturing output.

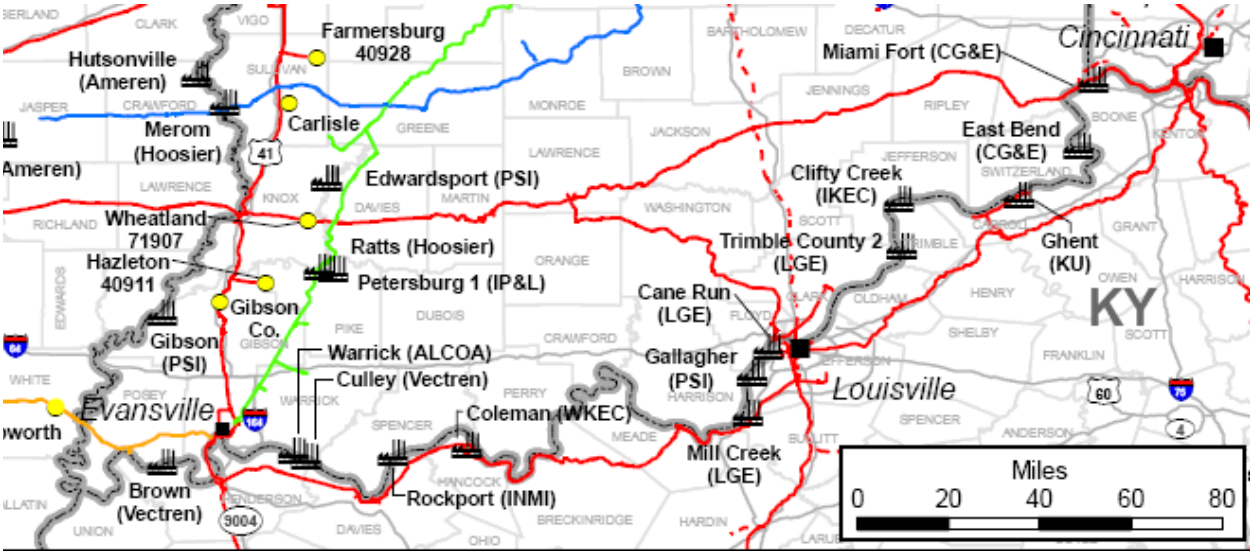

Figure 22. CSX map section for Indiana and Illinois along the Ohio River illustrating the CSX railroad tracks and coal powered electric generating plants. [46]

The Ohio River coal that is transported by barge is principally destined for the electric generation market along the river. The capacity requirements, in excess of one million railroad car loadings per year, could not be immediately met because there are not enough coal cars available to meet the initial demand for the increased transportation. The first impact therefore would be the need to provide rail cars for the coal. Since there is little if any excess coal car capacity, large car orders would need to be negotiated. Potentially all the rail car manufacturing capacity would be required to meet the initial car demand requirement. An estimation of a typical unit coal car cost is approximately $48,000 each.

Additional dedicated locomotives would also be required to be added to operate the new coal trains as coal cars are delivered to the system. Typical locomotive costs are estimated to be $2,000,000 each.

The number of rail cars needed can be estimated by making a few assumptions. First, the cycle time for the typical river diverted traffic to a coal train might only be two days from the coal mine to the utility and returning to the mine. However, since all train traffic may be assumed to

[46] CSX Railroad Coal Rate District map, Illinois and Indiana coal rate district. http://www.csx.com/share/customers/co_locations/docs/Illinois_and_Indiana-REF22631.pdf

be much slower because of the large amount of new traffic, existing coal trains sharing the affected routes would also have their cycle times increased, or, in other words, the existing coal trains using the route would be slowed down. A requirement of 1,010,250 coal loadings using 108 car unit trains will require 9,354 unit train initiations per year. Considering that each train requires two days per trip and there are only 365 days in the year, each train can only make 182.5 trips per year. Dividing the number of train initiations by the number of train trips per year for each additional train set, the minimum number of new train sets to meet the demand is 51.25 train sets. It is assumed any partial train set must be added as a whole train set and so there will need to be 52 train sets.

> The diversion of Ohio River Coal would require 156 new locomotives and 5,616 new coal cars immediately.

Typical coal trains of 100 or more loaded coal cars require three locomotives to operate safely and efficiently. A conservative estimate of 156 new locomotives would be needed to provide power for the new trains. The total number of new cars needed to meet the requirements for 52 new train sets is 5,616. The price tag for 156 new locomotives at a unit cost of $2,000,000 each is $312,000,000. At a unit cost of $48,000 each, the 5,616 new coal cars will cost $269,568,000. Together, the minimum equipment cost would be $581,568,000.

Many regulatory issues, operating concerns, and constraints are excluded from this example; for instance, the fact that every locomotive is required by regulation to have a substantial inspection four times each year is not considered in this example. The typical downtime for a scheduled 92-day locomotive inspection would be one day, where one day is the equivalent of one work shift. The inspection could easily take less time; however, if there were any unexpected events requiring extra shop time for minor repairs, the inspection event could exceed a 24-hour time period.

Referring to the example in Chapter 3, the system average train speed for the CSX system could go from approximately 19 mph down to less than 13 mph, or a decrease in system velocity of close to 45%. While it would be unreasonable to assume that all coal traffic on the CSX system would be impacted with a decrease in cycle times equal to the estimated system velocity reduction of 45%, it is not unreasonable to assume that if an increase in cycle time of 20% were to occur for existing traffic, the existing coal delivery traffic would require additional train sets to meet their current demand. Additional train sets would need to be added in order to recover the reduced train trip efficiency from adding so many new train sets to this single route.

> Diversion of river traffic could be expected to cause:
> - Increased demand for rail cars and locomotives
> - Higher freight rates
> - Need to expand infrastructure (rail lines)
> - Slower and less reliable delivery times

Because the current track capacity and train density along the CSX Ohio River route are unknown, it cannot be assumed that the addition of 52 additional train sets would introduce gridlock on the route. However, it can be assumed that the addition of 52 train sets would severely limit the operational efficiency of all trains on the route.

This is only one example of what might happen if any of the waterways were to be shut down. Regions outside the area discussed above might experience a more severe or less severe impact on rail operations, but the above illustration points out several effects that could be expected in almost every case:

- Increased demand for rail cars and locomotives
- Higher freight rates
- Need to expand infrastructure (rail lines)
- Potentially slower and less reliable delivery times
- Increased motor vehicle congestion at rail crossings
- Increased noise abatement issues

CHAPTER 8: A CASE STUDY – ST. LOUIS, MO

INTRODUCTION

This chapter uses a model developed by the Federal Highway Administration to estimate the impacts on highway traffic that would accrue in the event of a closure of the Illinois and Mississippi Rivers in the vicinity of St. Louis, Missouri. This model, known as "HERS-ST" is a very detailed and complicated model, typically used by traffic engineers for planning and budgeting purposes. The inputs and outputs are described—to the degree possible—in lay terms in this chapter.

Table 27 at the end of this chapter summarizes the impacts of a diversion of all waterborne traffic to the highways that are of most concern to the general public. The impacts are calculated as of 10 years after the waterway closure. The average speed on I-55 and I-255 will decrease by 6-11% during peak hours and up to 7% in off-peak hours. Hours of delay will be almost five times greater. Crashes, injuries, and fatalities will all rise by 36-45%. Emissions costs will rise by 37-52%.

HERS-ST OVERVIEW

The Highway Economic Requirements System-State Version (HERS-ST)[47] is a highway investment/performance software model that operates on a personal computer. It considers engineering and economic concepts and principles in determining the impact of alternative highway investment levels and program structures on highway condition, performance, and user impacts. HERS-ST offers a range of capabilities and potential uses. For example, HERS-ST can be used in program development, in "needs" analysis, and in establishing performance objectives. HERS-ST was developed by the Federal Highway Administration (FHWA) and is based on the Highway Economic Requirements System (HERS), which was also developed by the FHWA Office of Policy in order to bring economic principles and measures into its analyses of highway investment. The HERS model is used to estimate future investment requirements for pavement preservation and system expansion in the biannual Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance Report to Congress (C&P Report). (The latest report is the 2006 edition, which is the seventh in the series that combines information on the nation's highway and transit systems.)

HERS-ST estimates the investment required to achieve certain highway system performance levels. With the information produced from the analysis results, reports can then be generated using four different types of document formats – tables, reports, charts, or maps. One of several analytical scenarios provided by HERS-ST can be selected and then tailored by selecting from an array of values and parameters defined by the user. The analytical procedure relies on a database of records in the Highway Performance Monitoring System (HPMS) sample data format. This database supplies information regarding the highway system, particularly its current condition and performance. The analytical procedure involves identifying highway deficiencies and

[47] U.S. Department of Transportation. Federal Highway Administration. HERS-ST User's Guide Software Version 4.X. March 2007.

candidate improvements based on engineering standards. Finally, the analytical procedure selects the most economically worthwhile improvement projects according to economic criteria and scenario specifications provided by the user. The HERS-ST software is primarily intended for use by state or local Department of Transportation (DOT) officials who have a general understanding of the engineering and economic principles underlying highway decision-making activities, as well as access to their State's HPMS data, the primary data input.

The HERS-ST application allows for the evaluation of three general types of scenarios, which can be used for answering three specific questions:

- What level of spending is required to achieve an economically optimal program structure that implements all economically worthwhile projects?
- What user cost/condition/performance level will result from a given spending level?
- What level of spending is required to achieve a certain user cost level?

The general scenarios may be tailored by providing various input values such as the discount rate and deficiency levels. The default value for the overall length of the analysis period is 20 years, divided into four funding periods of five years each, but can be otherwise defined by the user. HERS-ST offers four primary types of analyses:

- Minimum BCR: Select for implementation all improvements with minimum benefit-to-cost ratios (BCR) exceeding a specified threshold
- Constraint by Funds: Maximize benefits as constrained by available funds
- Constraint by Performance: Maximize return on investment as constrained by performance
- Full Engineering Needs Analysis: Identify and correct all deficiencies

This case study analysis utilized the Minimum BCR and the Constraint by Funds types of analyses. The Minimum BCR analysis works on the premise of implementing all improvements with BCRs greater than a defined threshold value. The user must specify the minimum acceptable BCR for any implemented improvement. The Minimum BCR analysis addresses the following questions:

- What improvements exceed a specified minimum BCR?
- What level of investment would meet this BCR threshold?
- What will be the condition and performance of the highway system after investing at this level?

With the minimum BCR set to 1.0, HERS-ST will implement all cost-beneficial improvements. In doing so, it defines the upper limit of highway investment and maximum improvement in conditions and performance that could be economically justified. The FHWA calls this approach the Maximum Economic Investment scenario, which is used to help estimate the Cost to Improve Highways investment scenario in the Conditions and Performance (C&P) Report.

A minimum BCR analysis can also be used to define the cost of implementing the most economically attractive set of improvements that would meet a particular benchmark or goal, by iteratively changing the BCR threshold until the target is reached. For example, FHWA uses this approach to define the Cost to Maintain Highways scenario in the C&P Report, adjusting the

BCR threshold until average highway user costs at the end of the 20-year analysis period match those in the base year.

The Constraint by Funds analysis functions on the premise of maximizing the net present value of the benefits of improvements subject to specified constraints on funds available during each funding period, as specified by the user. The Constraint by Funds analysis addresses the following questions:

- How many improvements can be implemented at the specified level?
- What level of system condition and performance can be obtained when the improvements are implemented?

During each funding period, the model identifies potential improvements, and ranks them by BCR. After examining all sections, the model selects the most economically attractive improvements in order, until the available funds are expended or no economically justifiable candidate improvements remain.

A CASE STUDY: ST. LOUIS, MO

The HERS-ST software was utilized to evaluate and assess the impacts on roadway infrastructure, capacity, and public investment in the event of a hypothetical diversion of 100% of waterway freight to combination trucks. This case study is based on the metropolitan area surrounding St. Louis, Missouri for a variety of reasons:

- It is located along the Mississippi main stem at the confluence of the mouths of the Missouri and Illinois rivers.
- It is located at the intersection of several primary East-West and North-South interstate truck routes.
- It is the major truck highway bottleneck location along the Mississippi as seen in the figures in the congestion impacts analysis.
- The counties containing the St. Louis Missouri-Illinois metropolitan area have been designated "Nonattainment" or "Moderate" by the EPA for Clean Air Act's National Ambient Air Quality Standards (NAAQS) primarily for eight-hour Ozone and PM-2.5. Table 17 details the counties, pollutants, and respective classification standards of the most recent designations per the EPA's "Green Book"[48].

[48] U.S. Environmental Protection Agency. The Green Book: Nonattainment Areas for Criteria Pollutants. http://www.epa.gov/air/oaqps/greenbk/index.html, accessed September 2007.

Table 17. St. Louis Nonattainment Areas.

State	County	Pollutant & Classification Standard		
		8-Hr Ozone	PM-2.5	Lead
MO	Franklin	M	N	
	Jefferson	M	N	(part)
	St Charles	M	N	
	St Louis	M	N	
IL	Jersey	M		
	Madison	M	N	
	Monroe	M	N	
	Randolph		N	
	St Clair	M	N	
N=Nonattainment M=Moderate (less severe)				

Source: U.S. Environmental Protection Agency. The Green Book: Nonattainment Areas for Criteria Pollutants

Figure 23 shows a map of the latest EPA nonattainment county designations in the St. Louis MO-IL area as well as the urban interstate links, focusing on I-55 and I-255.

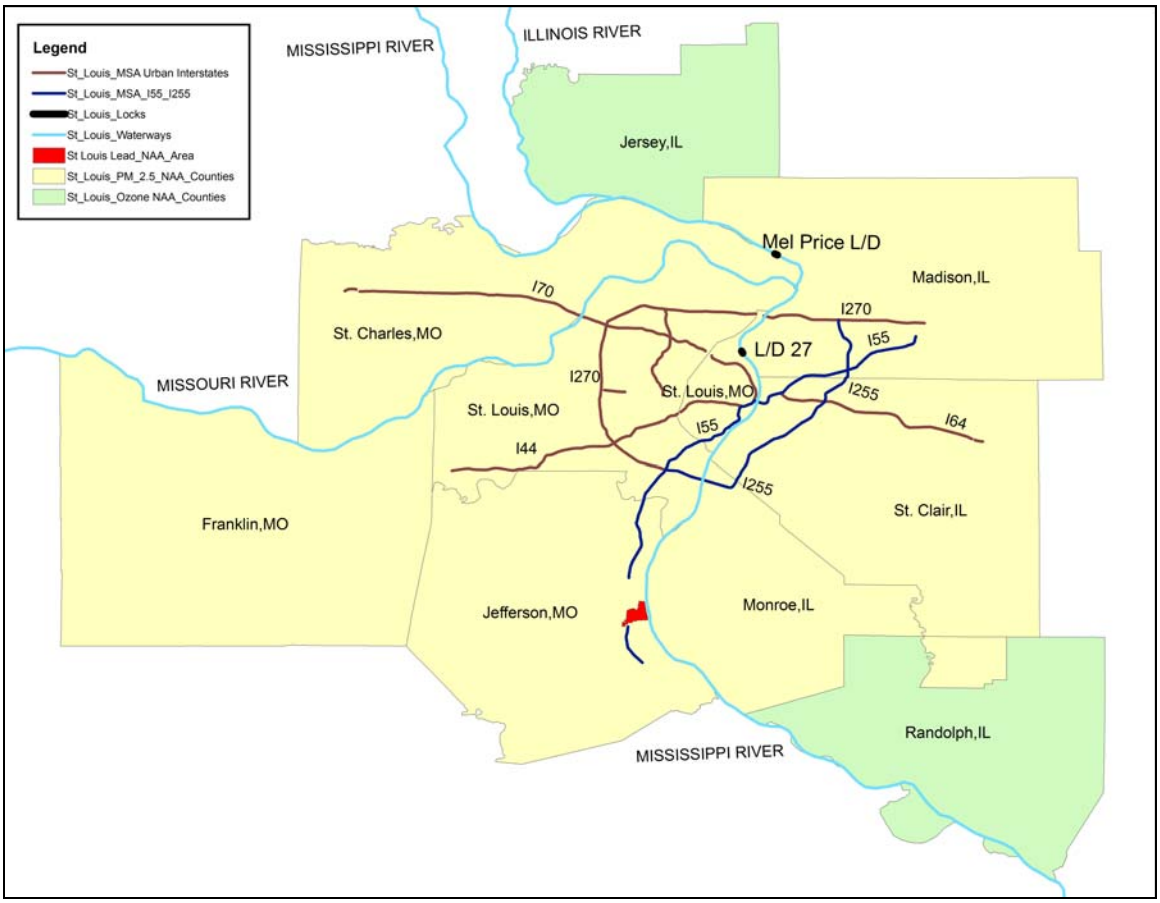

Figure 23. St. Louis Nonattainment/Maintenance Area.

There are two locks on the Mississippi river within the nonattainment area of St. Louis: Melvin Price Lock and Dam, and Lock and Dam 27. Data for the tons locked by each in 2005 were obtained from the U.S. Army Corps of Engineers' Waterborne Commerce of the U.S., also used previously in this study. The equivalent daily truck traffic that would have to traverse the area in the event of a theoretical freight diversion from barges to trucks was calculated in a manner similar to the analysis for the congestion impacts. The data and calculation results are shown in Table 18. Diversion of barge tonnage would add 14,780 combination trucks to the Average Annual Daily Traffic (AADT) through the St. Louis nonattainment area.

Table 18. St. Louis Lock Tonnage and Truck Traffic Equivalent.

St.Louis MSA Locks	Tons Locked 2005*			
	Downstream	Upstream	Total Annual	Total Daily**
Melvin Price	37,519,226	28,993,864	66,513,090	182,228
L/D 27	39,682,706	28,668,091	68,350,797	187,262
			Average Daily Tons	184,745
			Average Daily 25-ton Combination Trucks	7,390
			Average Daily Empty Backhaul Trucks	7,390
			Additional Average Daily Combination Trucks	14,780

*U.S. Army Corps of Engineers. Navigation Data Center. Waterborne Commerce of the United States 2005
**Assumes 365 days/year

The Mississippi river runs in a North-South direction, so it is logical to assume that any freight diversion from barges to trucks would also occur in the same direction. Therefore the AADT along I-55 and I-255, as seen in the map, would increase by an average of 14,780 vehicles per day, all of which would be combination trucks.

The reader should keep in mind that the assumptions and constraints detailed earlier in this report also pertain to this case study. These assumptions are imperative due to the "what if" nature of this analysis.

Data for 24 urban sections of I-55 and I-255 located within the St. Louis MO-IL nonattainment area were filtered from the 2005 Highway Performance Monitoring System sample section data into a Microsoft Excel file named "Current". The original dataset included current highway conditions as well as future forecasts of the AADT in year 2025. In other words this file served as the "as-is" or "control" case by assuming that no waterborne freight diversion will occur and current conditions will continue.

A second highway data file, named "Diversion" was created, which reflected the additional 14,780 combination trucks to the AADT of the 24 sections, and subsequent data modifications to the pertinent fields. The highway data in this file assume that diversion has occurred, and the 2025 AADT projections were adjusted accordingly.

Table 19 shows selected highway data fields of the HPMS, denoted by an asterisk, and their values in the Current file. The table also shows the results of subsequent calculations based on the reported values of the respective field(s). These calculations were conducted in order to determine the new values for these same fields that were input to the Diversion highway data file, shown in Table 20. Any discrepancies are attributable to rounding.

Table 19. Current Highway Data.

Section	Interstate	AADT*	K-Factor*	PHV	Average Daily Single Unit Trucks		Average Peak Hour Single Unit Trucks		Average Daily Combination Trucks		Average Peak Hour Combination Trucks		% Daily CTs in Peak Hour	V/SF*	Future AADT
					% AADT*	Number	% PHV*	Number	% AADT*	Number	% PHV*	Number	(Constant)		(2025)*
1	55	49,400	10	4,940	4	1,976	2	99	18	8,892	5	247	3	0.57	70,000
2	55	49,400	10	4,940	4	1,976	2	99	18	8,892	5	247	3	0.57	70,000
3	55	39,400	10	3,940	4	1,576	3	118	22	8,668	9	355	4	0.70	58,000
4	55	39,400	10	3,940	4	1,576	3	118	22	8,668	9	355	4	0.70	58,000
5	55	38,600	10	3,860	4	1,544	4	154	22	8,492	13	502	6	0.70	57,000
6	55	38,600	10	3,860	4	1,544	4	154	22	8,492	13	502	6	0.60	57,000
7	55	57,500	9	5,175	4	2,300	2	104	10	5,750	6	311	5	0.84	87,500
8	55	93,300	9	8,397	4	3,732	2	168	14	13,062	6	504	4	0.96	129,500
9	55	126,200	9	11,358	4	5,048	2	227	12	15,144	8	909	6	0.73	166,500
10	55	68,800	9	6,192	4	2,752	2	124	13	8,944	5	310	3	0.66	87,200
11	55	68,800	9	6,192	4	2,752	2	124	13	8,944	5	310	3	0.66	88,800
12	55	68,800	9	6,192	4	2,752	2	124	13	8,944	5	310	3	0.53	88,800
13	55	53,398	9	4,806	4	2,136	2	96	15	8,010	5	240	3	0.55	88,800
14	55	97,422	11	10,716	6	5,845	6	643	12	11,691	12	1,286	11	0.55	118,757
15	55	59,570	12	7,148	5	2,979	5	357	11	6,553	11	786	12	0.94	72,616
16	55	45,388	8	3,631	4	1,816	4	145	26	11,801	26	944	8	0.50	55,328
17	55	36,660	17	6,232	6	2,200	6	374	12	4,399	12	748	17	0.81	44,689
18	55	27,506	17	4,676	6	1,650	6	281	12	3,301	12	561	17	0.61	33,530
19	55	113,002	13	14,690	6	6,780	6	881	12	13,560	12	1,763	13	0.75	137,749
20	255	42,200	9	3,798	5	2,110	2	76	12	5,064	7	266	5	0.35	53,500
21	255	31,800	9	2,862	5	1,590	3	86	16	5,088	13	372	7	0.27	38,000
22	255	43,400	9	3,906	3	1,302	2	78	13	5,642	6	234	4	0.36	49,300
23	255	76,812	12	9,217	5	3,841	5	461	7	5,377	7	645	12	0.61	93,634
24	55	92,334	13	12,003	5	4,617	5	600	7	6,463	7	840	13	0.75	112,555

*HPMS Current Data
AADT=Average Annual Daily Traffic, vehicles per day
PHV=AADT*K=Peak Hour Volume, vehicles per hour
VHT=Vehicle Hours of Travel
K-Factor=Design Hour (taken here to mean the Peak Hour) Volume as a percent of AADT
V/SF=Volume to Service Flow Ratio = AADT*K*D/Peak Capacity
D=Directional Distribution; % PHV in peak direction
VMT=Vehicle Miles of Travel

Table 20. Diversion Highway Data.

Section	Interstate	Added Daily CTs	AADT*	Average Daily Combination Trucks		Added Peak Hour CTs	PHV	Average Peak Hour Combination Trucks		Average Daily Single Unit Trucks		Average Peak Hour Single Unit		K-Factor* (%)	D (%)	Capacity (vph)	V/SF*	Future AADT (2025)*
				Number	% AADT*			Number	% PHV*	Number	% AADT*	Number	% PHV*					
1	55	14,780	64,180	23,672	37	411	5,351	658	12	1,976	3	99	2	8	70	6,138	0.61	84,096
2	55	14,780	64,180	23,672	37	411	5,351	658	12	1,976	3	99	2	8	70	6,099	0.61	84,096
3	55	14,780	54,180	23,448	43	605	4,545	959	21	1,576	3	118	3	8	70	3,970	0.80	71,799
4	55	14,780	54,180	23,448	43	605	4,545	959	21	1,576	3	118	3	8	70	3,970	0.80	71,799
5	55	14,780	53,380	23,272	44	873	4,733	1,375	29	1,544	3	154	3	9	70	3,878	0.85	70,815
6	55	14,780	53,380	23,272	44	873	4,733	1,375	29	1,544	3	154	3	9	60	3,878	0.73	70,815
7	55	14,780	72,280	20,530	28	798	5,973	1,109	19	2,300	3	104	2	8	65	4,046	0.96	94,057
8	55	14,780	108,080	27,842	26	570	8,967	1,074	12	3,732	3	168	2	8	70	6,156	1.02	138,080
9	55	14,780	140,980	29,924	21	887	12,245	1,795	15	5,048	4	227	2	9	65	10,148	0.78	178,537
10	55	14,780	83,580	23,724	28	512	6,704	821	12	2,752	3	124	2	8	65	6,138	0.71	107,952
11	55	14,780	83,580	23,724	28	512	6,704	821	12	2,752	3	124	2	8	65	6,138	0.71	107,952
12	55	14,780	83,580	23,724	28	512	6,704	821	12	2,752	3	124	2	8	70	8,184	0.57	107,952
13	55	14,780	68,178	22,790	33	443	5,249	684	13	2,136	3	96	2	8	70	6,138	0.60	89,012
14	55	14,780	112,202	26,471	24	1,626	12,342	2,912	24	5,845	5	643	5	11	50	9,838	0.63	143,149
15	55	14,780	74,350	21,333	29	1,774	8,922	2,560	29	2,979	4	357	4	12	50	3,839	1.16	96,602
16	55	14,780	60,168	26,581	44	1,182	4,813	2,126	44	1,816	3	145	3	8	50	3,670	0.66	79,163
17	55	14,780	51,440	19,179	37	2,513	8,745	3,260	37	2,200	4	374	4	17	50	3,872	1.13	68,430
18	55	14,780	42,286	18,081	43	2,513	7,189	3,074	43	1,650	4	281	4	17	50	3,872	0.93	57,173
19	55	14,780	127,782	28,340	22	1,921	16,612	3,684	22	6,780	5	881	5	13	50	9,838	0.84	162,308
20	255	14,780	56,980	19,844	35	776	4,574	1,042	23	2,110	4	76	2	8	55	6,079	0.41	75,242
21	255	14,780	46,580	19,868	43	1,081	3,943	1,453	37	1,590	3	86	2	8	55	5,882	0.37	62,453
22	255	14,780	58,180	20,422	35	614	4,520	848	19	1,302	2	78	2	8	55	6,108	0.41	76,718
23	255	14,780	91,592	20,157	22	1,774	10,991	2,419	22	3,841	4	461	4	12	53	8,042	0.72	117,805
24	55	14,780	107,114	21,243	20	1,921	13,925	2,762	20	4,617	4	600	4	13	50	8,042	0.87	136,892

*HPMS New Data
AADT=Average Annual Daily Traffic, vehicles per day
PHV=AADT*K=Peak Hour Volume, vehicles per hour
VHT=Vehicle Hours of Travel
K-Factor=Design Hour (taken here to mean the Peak Hour) Volume as % of AADT
V/SF=Volume to Service Flow Ratio = AADT*K*D/Peak Capacity
D=Directional Distribution; % PHV in peak direction
VMT=Vehicle Miles of Travel

The values for the future AADT in the Diversion file were calculated by means of a linear regression equation developed from the AADT and the future AADT forecasts in the original HPMS file. An R^2 (r-squared) of 0.96 indicated that the forecasted y-values can be reliably estimated from the x-values using the equation--in other words the equation is a good fit to the data. The new, calculated AADT after the diversion was input as the x-value in the equation and the Future AADT (y-value) was developed and input to the Diversion file. Figure 24 shows the trend line developed, the equation, and the R^2.

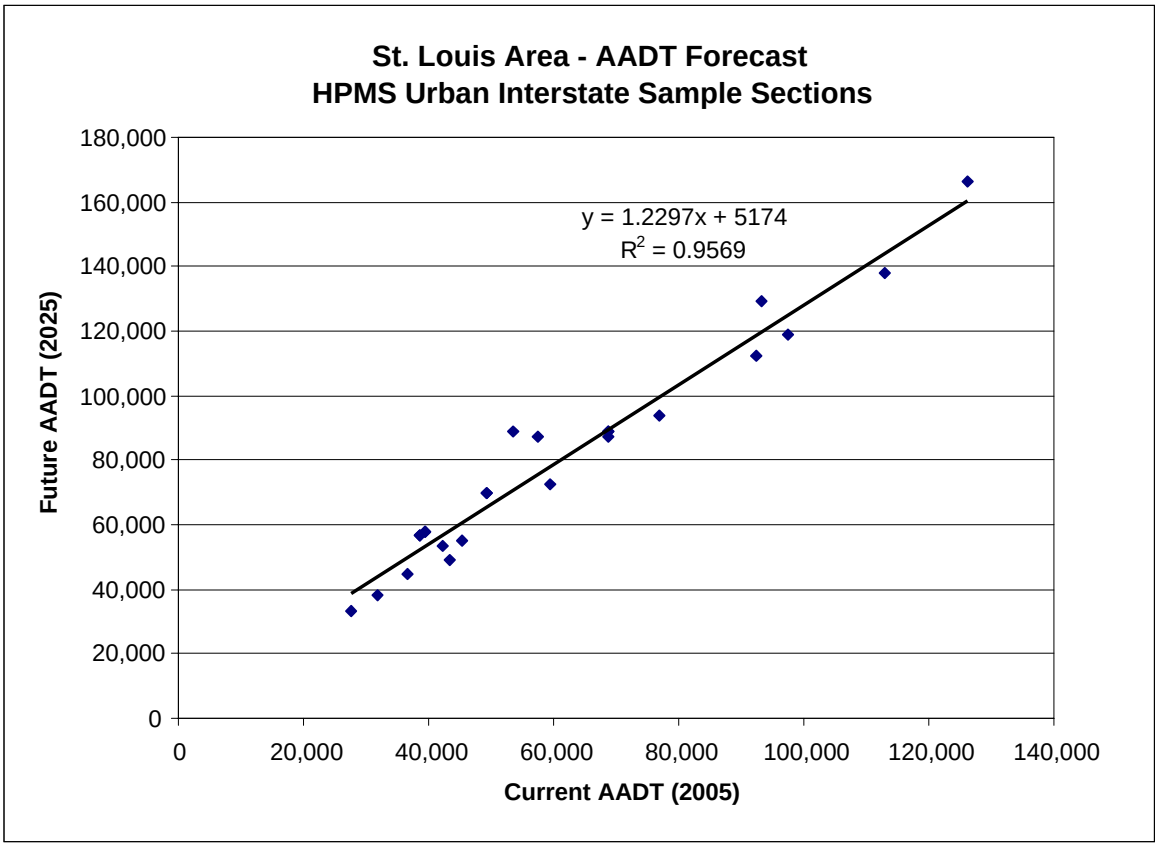

Figure 24. St. Louis Urban Interstate AADT Forecast.

Results

The HERS-ST output is very rich and detailed and is optimized for up to four funding periods of five years each, or a 20-year outlook. The maximum length of each funding period is seven years, so a 10-year outlook consisting of two funding periods, Funding Period 1 (FP1) and Funding Period 2 (FP2) was considered proper for this analysis. FP1 is for the time frame 0-5 years out and FP2 includes 5-10 years out.

Each of the two files, “Current” and “Diversion”, was input to HERS-ST and each was run under two types of analyses. The first analysis used the minimum BCR type, which was set to 1.0, in order to evaluate highway conditions and public investment required in FP1 and FP2. The second analysis used the Constraint by Funds type with the level of funding available for improvements in both funding periods set to zero. The objective was to evaluate the

uncompensated deterioration of highway conditions first without and then with diversion of the waterborne freight.

The output of the two minimum BCR runs consisted of System Conditions, System Deficiencies, and Improvement Statistics. The output of the two Constraint by Funds runs consisted of System Conditions and System Deficiencies only; since no funds were allocated, no improvements were implemented in either funding period. The output was rearranged and grouped in a meaningful manner for proper comparison of the various classifications of results given occurrence of a diversion or not, and given available funding or not.

With Improvements – Minimum BCR

Table 21 shows the System Conditions under the Current and Diversion scenarios, initially and at the end of each of the two funding periods, assuming that funds are available and HERS-recommended improvements with minimum BCR ratios of 1.0 have been implemented. This is the reason why some system condition indicators may not show significant changes between funding periods, or others (e.g., user costs) may show a decrease. In other words, the output can be thought of in terms of "What must be done, when must it be done, what will the benefits be, and what will be the cost to maintain or improve the system's performance given increased demand?"

Comparison of the initial category values to the values at the end of FP2 provides the best basis for contextual evaluation within each scenario as well as between them. In Table 21 the following categories are of interest:

- Category 2: Lane-Miles will only have to increase by 3 in 10 years' time under the Current scenario. They will have to increase by 37, or by more than 12 times (1,200%) under the Diversion scenario.
- Category 11: Total delay under Diversion is initially more than three times the Current and this ratio continues through FP2, a steady 300% difference.
- Category 14: VMT (Vehicle Miles Traveled) by Combination Trucks under Diversion is almost three times (300%) the Current due to the additional trucks, both initially and by FP2.
- Category 18: VHT (Vehicle Hours Traveled) by Combination Trucks under Diversion is more than three times (300%) the Current, both initially and by FP2. This reflects the increase in travel time, and increase in delay due to the congestion created by the additional truck traffic.
- Category 31: Infrastructure Maintenance Costs under Diversion are more than double (200%) those under Current, initially and by FP2.
- Category 32: Emissions Costs under Diversion are initially almost double (200%) the Current. By FP2 the difference drops and they are about 50% higher than the Current scenario.

Table 21. HERS Results: Current and Diversion System Conditions - with Improvements.

	Category	CURRENT			DIVERSION		
		Initial	FP 1	FP 2	Initial	FP 1	FP 2
1	Miles	96.2	96.2	96.2	96.2	96.2	96.2
2	Lane-Miles	636.6	639.4	639.4	636.6	642.6	673.8
3	Average PSR	3.43	3.68	3.60	3.40	3.27	3.49
4	Average IRI	90.8	72.0	74.9	92.5	99.4	81.5
5	Average Speed - Peak (mph)	69.9	69.9	69.1	67.7	67.2	65.5
6	Average Speed - Off Peak (mph)	70.8	70.8	70.7	70.7	70.7	70.6
7	Average Speed - Overall (mph)	70.5	70.5	70.2	69.8	69.6	68.9
8	Delay - Zero Volume (hrs per 1000 VMT)	0	0	0	0	0	0
9	Delay - Incident (hrs per 1000 VMT)	0.06	0.08	0.12	0.19	0.23	0.29
10	Delay - Other (hrs per 1000 VMT)	0.01	0.01	0.02	0.07	0.08	0.15
11	Delay - Total (hrs per 1000 VMT)	0.07	0.08	0.14	0.26	0.31	0.44
12	VMT - 4-Tire Vehicle (millions)	1,834	1,967	2,095	1,839	1,964	2,116
13	VMT - Single Unit Trucks (millions)	111	119	127	107	114	123
14	VMT - Combination Trucks (millions)	283	306	328	802	861	930
15	VMT - All (millions)	2,229	2,393	2,551	2,748	2,940	3,170
16	VHT - 4-Tire Vehicle (millions)	26	27	29	26	28	30
17	VHT - Single Unit Trucks (millions)	1	1	1	1	1	1
18	VHT - Combination Trucks (millions)	3	4	4	11	12	13
19	VHT - All (millions)	31	33	36	39	42	45
20	Travel Time Costs - 4-Tire Vehicle ($ per 1000 VMT)	280	281	283	286	287	290
21	Travel Time Costs - Trucks ($ per 1000 VMT)	458	459	463	483	487	496
22	Travel Time Costs - All ($ per 1000 VMT)	312	312	315	351	354	359
23	Operating Costs - 4-Tire Vehicle ($ per 1000 VMT)	309	297	299	305	310	298
24	Operating Costs - Trucks ($ per 1000 VMT)	767	732	733	793	783	752
25	Operating Costs - All ($ per 1000 VMT)	390	375	376	467	467	449
26	Crash Costs ($ per 1000 VMT)	74	75	75	75	76	76
27	Total User Costs ($ per 1000 VMT)	777	763	767	894	897	884
28	Crash Rate (per 100 million VMT)	154.7	155.2	155.8	156.5	157.2	157.7
29	Injury Rate (per 100 million VMT)	75.9	76.1	76.5	76.8	77.2	77.4
30	Fatality Rate (per 100 million VMT)	0.6	0.6	0.6	0.6	0.6	0.6
31	Maintenance Costs ($ per 1000 miles)	790,891	430,964	498,640	1,749,975	1,418,868	1,421,410
32	Emissions Costs ($ per 1000 VMT)	32.88	19.96	12.28	57.27	32.56	18.68
33	BCR of Last Improvement	--	2.7	1.2	--	1.8	1.1

Notes:
Funding Periods: 1: 0-5 years & 2: 5-10 years from now (initial)
PSR = Present Serviceability Rating. The higher the PSR the better the pavement. I New pavements at max PSR = 4.5-5.0
IRI = International Roughness Index. The higher the IRI the worse the pavement.
V/C Ratio or VCR = Volume to Capacity Ratio; traffic jams (system failures) occur at V/C=1
VMT = Vehicle Miles of Travel
VHT = Vehicle Hours of Travel
BCR = Benefit Cost Ratio
Any discrepancies in calculations due to intermediate rounding

Table 22 shows selected categories from the System Deficiencies output of HERS. Deficiencies in Pavement Serviceability Rating, Volume-to-Capacity (V/C) Ratio, and Shoulder Surface are reported in percent miles and percent vmt that are deficient, initially and at the end of each funding period.

Under the Current scenario all three categories are remedied by FP2, given implementation of improvements, since the percent deficient miles and vmt both drop substantially by FP2.

Under the Diversion scenario, only PSR and shoulder deficiencies are remedied by FP2. The V/C ratio deficiencies however, worsen by FP2 despite improvements. Both the deficient percent miles and the deficient percent vmt more than double from initial to FP2, from 6 to 12 and from 5 to 13 respectively. FP2 V/C ratio deficiencies are roughly 15 times the FP2 levels under Current, 12.3 vs. 0.8 percent miles and 12.7 vs. 0.7 percent vmt.

Table 22. HERS Results: Current and Diversion System Deficiencies - with Improvements.

Deficiency Category		CURRENT			DIVERSION		
		Initial	FP 1	FP 2	Initial	FP 1	FP 2
	% MILEAGE						
1	PSR (<3.4)	47.9	15.3	11.2	47.9	70.9	14.5
2	V/C Ratio (>0.9)	1.7	0.8	0.8	6.1	11.4	12.3
3	Shoulder Surface Type*	43.2	--	--	43.2	--	--
	% VMT						
1	PSR (<3.4)	36.3	25.3	13.8	38.5	69.3	21.2
2	V/C Ratio (>0.9)	2.0	0.7	0.7	4.9	12.3	12.7
3	Shoulder Surface Type*	27.3	--	--	30.3	--	--

*Shoulder width not all concrete.

Table 23 shows selected improvement statistics output by HERS. The three categories of improvements identified are:

- Resurfacing, including adding new lanes - or major widening
- Resurfacing the existing lanes, including the shoulders
- Resurfacing the existing lanes only

These improvements are estimated to cost four times as much in FP2 under the Diversion by comparison to the Current ($479m vs. $119m). The total lane-miles to be improved by FP2 under Diversion are almost three times as many as under Current (584 vs. 202). The total miles to be improved, by FP2 under Diversion are also almost three times as many as under Current (80 vs. 30).

Table 23. HERS Results: Current and Diversion Improvement Statistics.

Category	CURRENT		DIVERSION	
	FP 1	FP 2	FP 1	FP 2
1 **Cost ($ 000s)**				
Resurface and add Normal-Cost Lanes (major widening)	19,265	--	40,596	235,568
Resurface and Improve Shoulders	157,007	--	152,092	--
Resurface	49,530	119,242	49,530	243,744
Total	225,803	119,242	242,219	479,312
2 **Lane-Miles Improved**				
Resurface and add Normal-Cost Lanes (major widening)	10	--	19	170
Resurface and Improve Shoulders	218	--	212	--
Resurface	95	202	95	413
Total	323	202	327	584
3 **Miles Improved**				
Resurface and add Normal-Cost Lanes (major widening)	1	--	3	15
Resurface and Improve Shoulders	41	--	39	--
Resurface	14	30	14	64
Total	57	30	57	80

Without Improvements – Constraint by Funds

Table 23 shows the System Conditions under the Current and the Diversion scenarios, initially and at the end of each of the two funding periods, assuming that no funds are available and no improvements have been implemented. This output can be thought of in terms of "What will the system's condition and performance be if nothing is done?"

Comparison of the initial category values to the values at the end of FP2 provides the best basis for contextual evaluation within each scenario as well as between them. In Table 23 the following categories are of interest:

- Category 2: Lane-Miles do not increase under either scenario; since no funds are available, no construction has taken place.
- Category 11: Total delay under Diversion is roughly three times the Current from initial through to FP2, a steady 300% difference.
- Category 14: VMT (Vehicle Miles Traveled) by Combination Trucks under Diversion is almost three times (300%) the Current due to the additional trucks, both initially and by FP2.
- Category 18: VHT (Vehicle Hours Traveled) by Combination Trucks under Diversion is more than three times (300%) the Current from initial to FP2. This reflects the increase in travel time, and increase in delay due to the congestion created by the additional truck traffic.
- Category 31: Infrastructure Maintenance Costs under Diversion are more than double (200%) those under Current scenario, initially and by FP2.
- Category 32: Emissions Costs under Diversion are initially almost double (200%) the Current. By FP2 the difference drops to about 1.4 times the Current scenario (40% higher).

Table 24. HERS Results: Current and Diversion System Conditions - w/o Improvements.

	Category	CURRENT			DIVERSION		
		Initial	FP 1	FP 2	Initial	FP 1	FP 2
1	Miles	96.2	96.2	96.2	96.2	96.2	96.2
2	Lane-Miles	636.6	636.6	636.6	636.6	636.6	636.6
3	Average PSR	3.43	2.99	2.61	3.40	2.52	1.90
4	Average IRI	90.8	127.9	165.0	92.5	173.6	247.7
5	Average Speed - Peak (mph)	69.9	69.5	68.5	67.7	65.8	62.0
6	Average Speed - Off Peak (mph)	70.8	70.7	70.2	70.7	69.4	66.1
7	Average Speed - Overall (mph)	70.5	70.3	69.7	69.8	68.2	64.8
8	Delay - Zero Volume (hrs per 1000 VMT)	0	0	0	0	0	0
9	Delay - Incident (hrs per 1000 VMT)	0.06	0.08	0.11	0.19	0.23	0.28
10	Delay - Other (hrs per 1000 VMT)	0.01	0.02	0.04	0.07	0.10	0.14
11	Delay - Total (hrs per 1000 VMT)	0.07	0.10	0.14	0.26	0.33	0.42
12	VMT - 4-Tire Vehicle (millions)	1,834	1,930	2,013	1,839	1,923	1,990
13	VMT - Single Unit Trucks (millions)	111	117	122	107	111	115
14	VMT - Combination Trucks (millions)	283	299	313	802	837	868
15	VMT - All (millions)	2,229	2,346	2,448	2,748	2,873	2,973
16	VHT - 4-Tire Vehicle (millions)	26	27	28	26	28	30
17	VHT - Single Unit Trucks (millions)	1	1	1	1	1	1
18	VHT - Combination Trucks (millions)	3	4	4	11	12	13
19	VHT - All (millions)	31	33	35	39	42	45
20	Travel Time Costs - 4-Tire Vehicle ($ per 1000 VMT)	280	281	284	286	290	300
21	Travel Time Costs - Trucks ($ per 1000 VMT)	458	462	473	483	508	559
22	Travel Time Costs - All ($ per 1000 VMT)	312	313	317	351	362	385
23	Operating Costs - 4-Tire Vehicle ($ per 1000 VMT)	309	331	352	305	350	382
24	Operating Costs - Trucks ($ per 1000 VMT)	767	821	865	793	897	952
25	Operating Costs - All ($ per 1000 VMT)	390	418	444	467	530	571
26	Crash Costs ($ per 1000 VMT)	74	75	75	75	76	76
27	Total User Costs ($ per 1000 VMT)	777	807	837	894	969	1033
28	Crash Rate (per 100 million VMT)	154.7	155.1	155.5	156.5	157.1	157.7
29	Injury Rate (per 100 million VMT)	75.9	76.1	76.3	76.8	77.1	77.4
30	Fatality Rate (per 100 million VMT)	0.6	0.6	0.6	0.6	0.6	0.6
31	Maintenance Costs ($ per 1000 miles)	790,891	978,436	1,147,186	1,749,975	2,125,590	1,526,905
32	Emissions Costs ($ per 1000 VMT)	32.88	19.87	12.08	57.27	31.39	16.86

Notes:
Funding Periods: 1: 0-5 years & 2: 5-10 years from now (initial)
PSR = Present Serviceability Rating. The higher the PSR the better the pavement. I New pavements at max PSR = 4.5-5.0
IRI = International Roughness Index. The higher the IRI the worse the pavement.
V/C Ratio or VCR = Volume to Capacity Ratio; traffic jams (system failures) occur at V/C=1
VMT = Vehicle Miles of Travel
VHT = Vehicle Hours of Travel
BCR = Benefit Cost Ratio
Any discrepancies in calculations due to intermediate rounding

Table 25 shows selected categories from the System Deficiencies output of HERS. Deficiencies in Pavement Serviceability Rating, Volume-to-Capacity Ratio, and Shoulder Surface are reported in percent miles and percent vmt that are deficient, initially and at the end of each funding period.

Under the Current scenario the percent miles and percent vmt that are deficient in V/C ratio and shoulder surface increase modestly from initial to FP2. However, PSR deficiency at FP2 is at least 1.5 times the initial levels, from 48 to 72 percent miles and from 36 to 67 percent vmt.

Under the Diversion scenario, no change is shown in percent miles or vmt that are deficient in shoulder surface. PSR deficiency however, almost doubles by FP2, from 48 to 93 percent miles and more than doubles in percent vmt, from 39 to 90. Overall vmt deficiencies are roughly 200% the initial levels or a 100% increase.

V/C ratio deficiencies under Diversion from initial to FP2 more than double in percent miles (6 to 15), and more than triple in percent vmt (5 to 16). By comparison to FP2 under the Current scenario, the V/C ratio deficiencies in percent miles and percent vmt are over six times as much.

Table 25. HERS Results: Current and Diversion System Deficiencies - w/o Improvements.

Category		CURRENT			DIVERSION		
		Initial	FP 1	FP 2	Initial	FP 1	FP 2
	% MILEAGE						
1	PSR (<3.4)	47.9	72.2	72.2	47.9	89.9	93.2
2	V/C Ratio (>0.9)	1.7	2.2	2.2	6.1	14.6	14.6
3	Shoulder Surface Type*	43.2	43.2	43.2	43.2	43.2	43.2
	% VMT						
1	PSR (<3.4)	36.3	67.7	67.5	38.5	88.1	90.4
2	V/C Ratio (>0.9)	2.0	2.5	2.6	4.9	15.5	15.7
3	Shoulder Surface Type*	27.3	27.7	27.9	30.3	30.0	30.0

*Shoulder width not all concrete.

Table 26 consolidates the wide spectrum of impacts on the interstate system that would be expected in case of a diversion of the Mississippi river freight traffic through the St. Louis area. The comparison focuses on selected categories, with and without improvements, under the current and the diversion scenarios, initially and 10 years hence.

Table 26. Summary of HERS Results - Engineering.

IMPACT	IMPROVEMENTS	CURRENT		DIVERSION	
		Initial	In 10 Years	Initial	In 10 Years
New Construction (lane-miles)	Yes	636.6	639.4	636.6	673.8
	No	636.6	636.6	636.6	636.6
Delay (hrs/1,000 VMT)	Yes	0.07	0.14	0.26	0.44
	No	0.07	0.14	0.26	0.42
VMT Combination Truck (millions)	Yes	283	328	802	930
	No	283	313	802	868
VHT Combination Truck (millions)	Yes	3	4	11	13
	No	3	4	11	13
Maintenance Costs ($000s/1,000 VMT)	Yes	791	499	1,750	1,421
	No	791	1,147	1,750	1,527
Emissions Costs ($/1,000 VMT)	Yes	33	13	57	19
	No	33	12	57	17
% VMT with Deficient PSR	Yes	36.3	13.8	38.5	21.2
	No	36.3	67.5	38.5	90.4
% VMT with Deficient V/C Ratio	Yes	2.0	0.7	4.9	12.7
	No	2.0	2.6	4.9	15.7
Improvement Costs ($ million)	Yes	345		722	
	No	--		--	

Table 27 further consolidates the wide spectrum of impacts on the interstate system that would be expected in case of a diversion of the Mississippi river freight traffic through the St. Louis area. The comparison focuses on 10 selected categories deemed to be the items of greatest interest to the general public. It shows present conditions (from Current initial output), as well as conditions in 10 years (end of FP2) under the Diversion scenario, both with and without cost-effective improvements to account for the additional traffic. The present conditions serve as the baseline values on which the percent change has been calculated. Assuming all cost-effective improvements (benefits exceed costs) were undertaken, the analysis concluded that highway improvement costs over 10 years would increase from $345 million to $722 million. Truck traffic would almost triple. Traffic delays would increase by almost 500%. Injuries and fatalities on these highway segments would increase by 36-45%. Maintenance costs would

increase by 80-93%. While a permanent shutdown of the waterway certainly cannot be anticipated, this case study demonstrates how beneficial the waterways are to the overall freight transportation system.

Table 27. Summary of Significant Impacts - General Public.

	Category	CURRENT Initial	10 YEARS AFTER WATERWAY CLOSURE			
			w/o Improvements	% Change	w Improvements	% Change
1	Combination Trucks per Lane-Mile per Day*	1218	3736	207%	3781	210%
2	Average Speed - Peak (mph)	69.9	62.0	-11%	65.5	-6%
3	Average Speed - Off Peak (mph)	70.8	66.1	-7%	70.6	0%
4	Delay - Total (hrs per 1000 VMT)	0.07	0.42	466%	0.44	495%
5	Crashes (annual)	3448	4688	36%	4999	45%
6	Injuries (annual)	1692	2301	36%	2454	45%
7	Fatalities (annual)	13	18	36%	19	45%
8	Maintenance Costs ($ million per 1000 miles)	0.79	1.53	93%	1.42	80%
9	Emissions Costs ($ per 1000 VMT)**	12.28	16.86	37%	18.68	52%
10	Improvement Costs ($ million)***	345.0	--	--	721.5	109%

* Calculated from HERS Output as: VMT Combination Trucks / (Lane-Miles x 365)

** Value from Current w/ Improvements FP2 output. Cleaner vehicles are expected to be in use 10 years from now, under either scenario.

*** Value from Current w/ Improvements FP2 output