FINAL REPORT

SYNTHESIZING COMMERCIAL SHIPPING (BARGE/TUG TRAINS) FROM AVAILABLE DATA FOR VESSEL COLLISION DESIGN

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1. INTRODUCTION

During the period of 1960 to 1993, major ship collisions with bridges have happened nearly 30 times in the world. Several most catastrophic failures of these collisions include the collapse of the Sunshine Skyway Bridge (1980) with loss of 35 lives, Volga River Railroad Bridge (1983) with loss of 176 lives, and the Alabama railroad Bridge (1993) with loss of 44 lives (Lexington Herald-Leader 1993 and Mastaglio 1997). Even though there is no loss of life involved, severe strike can cause traffic close for hours, such as the accident of the U.S. 51 and 62 bridge over the Ohio River on April 23, 1995 (Lexington Herald-Leader 1995). Since 1960, the number of U.S. bridges that cross major waterways at coastal ports has increased 33% while the number of vessels in the world has increased threefold. This fact means an increasing possibility of disastrous collisions worldwide as a result. Furthermore, inadequate attention is often given to a bridge's relationship with waterborne traffic and bridges are placed over the navigation channel that does not accommodate the modern ships and barges/tugs that regularly exceed 800 ft (243.84m) in length and 100 ft (30.48m) in width. The risk is compounded when strong winds or difficult current conditions create a challenging environment for steering.

Only after the catastrophe of the Sunshine Skyway Bridge (1980) has action been taken in the U.S. to standardize protection procedures for bridges. Many bridges each year are designed to resist vessel impact loads according to the American Association of State Highway and Transportation Officials (AASHTO) *Guide specification and commentary for vessel collision design of highway bridges* (1991). The guide specification provides three vessel impact design method, called method I, II, and III. Method I is a semi-deterministic procedure that allows the designer to select a design vessel for collision impact. Method II is a probability-based technique in which the design vessel is selected based on accurate vessel traffic data. Method III employs a cost-effective analysis procedure to select the design vessel for collision impact and closely parallels techniques used in Method II. Most bridges are designed using Method I because it is simple and easy to use. Although more difficult to apply than Method I, design Method II is recommended by the AASHTO *Guide Specification* (1991) for most bridges. However, the guide specification provides very little guidance on the application of design Method II to bridges susceptible to barge/tug impact since it focuses mainly on ship impact design.

The objective of this project is to establish the commercial shipping traffic for all bridges located over navigable waterways in Florida. Knowing the commercial shipping traffic, a risk analysis can be performed which optimizes the vessel collision design. This data will be developed on a statewide basis so that the commercial vessel traffic can be provided to the design teams. This work will result in reducing bridge design and construction cost by use of consistent data for all bridge sites and uniform application of the risk analysis approach. It is estimated that 401 bridge sites are qualified for this synthesization process.

2. TECHNOLOGY REVIEW

2.1 AASHTO GUIDE SPECIFICATION DESIGN METHOD II

When performing vessel impact risk analysis according to design Method II, the AASHTO *Guide Specification and Commentary for Vessel Collision Design of Highway Bridges* (1991) requires the following data: (1) vessel characteristics; (2) waterway characteristics; (3) bridge characteristics; (4) design impact speed; and (5) probability of aberrancy, etc. According to FDOT's technical needs, our major work focus on performing, collecting, and processing data from available sources on items (1) and (4).

Figure 1 demonstrates the design flowchart of Method II in the AASHTO *Guide Specification* (1991). To apply this design code to the new bridges in Florida, it is necessary to discuss these data together with the inland waterway situations within this state. Following the design Method II procedure, the FDOT has developed a risk analysis software in the environment of Mathcad for vessel impact resistant design.

Design Vessel Acceptance Criteria

The AASHTO *Guide Specification* (1991) defines the acceptance criteria for two bridge classifications: regular and critical bridges. For regular bridges, the acceptable annual frequency of collapse for the total bridge elements, AF, should be equal to , or less than, 0.1 in 100 years ($AF = 0.001$). For critical bridges, the acceptable annual frequency of collapse, AF, should be equal to , or less than, 0.01 in 100 years ($AF = 0.0001$). The design Method II suggests that this acceptable annual frequency of collapse for the total bridge be distributed over the number of pier and span elements located within the waterway, or within the distance $3 \times LOA$ (LOA is the length overall of ship or barge tow) on each side of the inbound and outbound vessel transit paths if the waterway is wide. This distribution results in a reasonable risk over each bridge pier and span element. It is recommended that the failure probability be distributed to achieve a uniform risk level over all bridge components.

Annual Frequency of Collapse

According to the design Method II, the annual collapse frequency of the jth bridge component shall be computed by

$$AF_j = \sum_{i=1}^{n} N_i \cdot PA_j \cdot PG_{i,j} \cdot PC_{i,j} \tag{1}$$

where

AF_j = annual frequency of the jth bridge component collapse due to vessel collision, $j = 1, \cdots, m$, and m is the total number of bridge components susceptible to vessel collision;

N_i = annual number of the ith vessel group classified by type, size, and loading condition which can strike the bridge element, $i = 1, \cdots, n$, and n is the total number of classified vessel groups;

PA_j = probability of vessel aberrancy at the jth bridge component;

$PG_{i,j}$ = geometric probability of a collision of an aberrant vessel in the ith group with the jth bridge component; and

$PC_{i,j}$ = probability of the jth bridge component collapse due to a collision with an aberrant vessel in the ith group

Vessel Characteristics

In the design Method II of the AASHTO *Guide Specification* (1991), the sizes, annual passages, displacement capacity, and draft at movement of every vessel passing under the specific bridge should be determined. It is recommended that a detailed database maintained by U.S. Army Corps of Engineers Waterborne Commerce Statistics Center, New Orleans, LA, be utilized for collecting relevant vessel traffic data at a particular bridge site. To request waterborne traffic information from this database, coordinates of the specific bridge location, namely past point, shall be provided to the WCSC. The experts at WCSC firstly locate the past point through the Geographical Information System (GIS), then survey data for this point from its adjacent waterway joints. According to the WCSC classification system, inland navigation vessels are classified into six types: (1) self propelled (dry cargo); (2) self propelled (tanker); (3) towboat;

(4) non-self propelled (dry cargo); (5) non-self propelled (tanker); and (6) other. Among these vessels, types 1 and 2 with power system stand for ships, and types 4 and 5 without power system stand for barges. In most inland and intracoastal waterways of Florida, the statistically significant vessel traffic is typically barge flotilla traffic. When flotillas are dominant in waterway traffic, one of the difficulties in the application of design Method II lies in that there are tremendous variation in flotilla sizes and barge types and sizes. Through contacting with local barge and ship companies, it was informed that the flotillas in Florida mainly comprise one tug and one barge combination, except for the north-west part of the state where there are transit flotillas consisted of one tug and several barges to meet the need of heavy waterway transportation. A FORTRAN computer program was written to synthesize the requested data from the WCSC database and to classify the barges into different groups.

Probability of Aberrancy

The probability of aberrancy is a vessel casualty probability to the bridge, caused by human errors, poor environmental conditions, and mechanical failures, etc. The AASHTO *Guide Specification* (1991) recommends that PA be determined on the basis of historical accident data for a particular bridge site. Otherwise, an alternative estimation can be used for the bridge location:

$$PA = BR \cdot R_B \cdot R_C \cdot R_{XC} \cdot R_D \tag{2}$$

where

BR = aberrancy base rate derived from historical accident data from several U.S. waterways: for ship 0.6×10^{-4} and for barges 1.2×10^{-4}; and

R_B, R_C, R_{XC}, R_D = correction factors for bridge location, current acting parallel and perpendicular to vessel transit path, and vessel traffic density, respectively.

Geometric Probability

The geometric probability is a conditional probability that a vessel will hit a bridge pier or span given that it has lost control in the vicinity of the bridge as shown in Figure 2. The AASHTO *Guide Specification* (1991) recommends that the geometric probability be computed based on a normal distribution of vessel accidents about the centerline of the vessel transit path and the standard deviation be taken as LOA. These recommendations primarily come from investigation of accident data from ship vessels. However, little research has been made for the distribution form of barge accidents over an inland waterway. It is suggested that the distribution type of ship or barge accidents be investigated to acquire its more accurate description and the distribution type be determined in association with channel profile characteristics and vessel draft at movement. In the situation that the vessel draft of the ith group is greater than the water depth of channel at the jth bridge pier, $PG_{i,j}$ is zero, rather than the shadow area as shown in Figure 2. Other distribution types can also be applied, such as Lognormal type or Extreme I type, depending on the actual profile of water depths in waterway.

Probability of Collapse

The probability of collapse means a measure of risk of the bridge failure once it has been struck by an astray vessel.

$$PC = \begin{cases} 0.1 + 9(0.1 - H/P) & for\ 0.0 \le H/P < 0.1 \\ (1 - H/P)/9 & for\ 0.1 \le H/P < 1.0 \\ 0.0 & for\ H/P \ge 1.0 \end{cases} \qquad (3)$$

where

H = ultimate bridge element strength; and

P = vessel impact force.

The definition of probability of collapse in Eq. (3) is based on the historical damage statistics caused between two colliding ships at sea (Fujii 1978). This definition does not reflect the structural design philosophy of bridge components. From the viewpoint of structural reliability analysis (e.g., LRFD Bridge Design Specifications 1994), PC does not equal zero, for $H/P > 1.0$, since both ultimate strength H and vessel impact force P are actually random variables due to inevitable construction and theoretical errors. In the case that H and P are two independent normal distributed variables (mean values: 1100 and 1000, standard deviations: 50 and 50, respectively, unit: kips), the probability of failure under the limit state $H - P = 0$ is 0.08, rather than zero.

Vessel Collision Force

The ship collision equivalent static impact force on pier shall be computed by the following:

$$P_S = 220(DWT)^{1/2}\left(V/27\right) \text{ kips} \tag{4}$$

where

DWT = deadweight tonnage of ship (tonnes); and

V = ship impact speed (fps).

The barge collision equivalent static impact force on pier shall be determined by the following:

$$P_B = \begin{cases} 4112 \cdot a_B \cdot R_B \quad \mathit{for}\ a_B < 0.34; \\ \left(1349 + 110 \cdot a_B\right) \cdot R_B \quad \mathit{for}\ a_B \geq 0.34 \end{cases} \text{ kips} \tag{5}$$

where

R_B = ratio of $B_B/35$;

B_B = barge width (ft); and

a_B = $[\left(1 + KE/5672\right)^{1/2} - 1] \cdot \left(10.2/R_B\right)$, barge bow damage depth (ft), and KE is vessel collision energy (kip-ft).

2.2 SIMMILAR EFFORTS

In recent years, theoretical analyses and field tests on the structural protection design of bridge against ship collision have been performed (Arita et al 1994, Hansen et al 1994, Kuzmanovic and Sanchez 1992, Poepsel and Dowd 1995, Rambech and Dahl 1994, and Whitney et al 1996). Risk modeling of vessel impact on bridges are investigated (Bein 1993, Grabowski and Wallace 1993, Gravesen et al 1995, and Knott 1996) for the purpose of structural design. A cable-stayed bridge over the Ohio River at Maysville, Kentucky, was given as a detailed design example by design Method II (Whitney et al 1996). In the example, a probability-based approach is recommended to be adopted to calculate the number of barges comprising a flotilla due to the large variation in the flotillas. However, the efforts are needed to collect and process the necessary waterway traffic information in Florida for the vessel collision resistant evaluation of existing bridges or new bridge designs using Method II.

3. FLORIDA VESSEL FLEET CHARACTERISTICS

In the famous waterways, such as Mississippi River System and Kentucky Waterways, vessel characteristics can be acquired from the information contained in the *Waterborne Transportation Lines of the United States* database (Whitney et al 1996). However, there are various complicated waterways in Florida, including canals, rivers, and intracoastal areas etc. In the project, past points are selected all over the Florida waterways to obtain the vessel traffic data. These past points are sent to the Navigation Data Center (NDC) of U.S. Army Corps of Engineers in order to request data. A Fortran program is developed to process these data according to the fixed format , which is formed by FDOT.

3.1 PAST POINTS

The U.S. Army Corps of Engineers is responsible for the operation and maintenance of the Nation's waterway system to insure efficient and safe passage of commercial and recreational vessels. The support and management of economically sound navigation projects is dependent upon reliable navigation data. The Water Resources Support Center's Navigation Data Center (NDC) is responsible for establishing and maintaining a variety of navigation-oriented databases. These include databases of waterborne commerce, domestic commercial vessels, port facilities, lock facilities and lock operations, and navigation dredging projects.

The NDC's main office in Alexandria, Virginia, houses all but the waterborne commerce and vessels databases. These databases are operated and maintained by the NDC's Waterborne Commerce Statistics Center (WCSC) in New Orleans, Louisiana. Although organizations within the Corps of Engineers are the primary users, the data and information are available to all government agencies, organizations, and individuals.

The FDOT Data, the table “Bridges with Navigation Control” and the bridge location maps marked with the bridge numbers in Florida, have been studied to decide the past points. The selection of past points is primarily based on the following two principles:

- Basically each major river/canal of every county possesses one past point;
- Bridge site of a moveable structural type is an optional past point.

When these points have been approved by FDOT, a total number of 52 bridge locations has been chosen as past points to represent 540 bridges with navigation control all over Florida. The coordinates of these past points are shown in **Appendix I**. In **Appendix I**, a Florida map distributed with the 52 past points is also drawn by using the Geographical Information System (GIS). In addition to the requested data, the WCSC sent a set of maps with detailed geographical information on each past point as shown in **Appendix I**. One-year and three-year data for these points has been requested and purchased from the WCSC. Contacted persons and address are listed as follows:

Mr. Ed Drinkert at Tel: (504) 862-1429 FAX: (504) 862-1423
or
Ms. Charlotte Cook at Tel: (504) 862-1473 FAX: (504) 862-1423

Waterborne Commerce Statistics Center

Navigation Data Center

U.S. Army Corps of Engineers

P. O. Box 61280

New Orleans, LA 70161-1280

According to the *Waterborne Commerce Of The United States 1997 parts 1 thru 5*, annual tonnages may significantly vary in some waterway areas in Florida. This means one-year data may lead to unreasonable statistical results. Consequently, all 52 past points have been distributed into different waterway areas listed in the book (see **Appendix II**), e.g., past points 3, 5, 6, 7, 14, 28, 33, 34, 36, 44, 45, 47, 48, 50, 51, and 52 belong to the area INTRACOASTAL WATERWAY, JACKSONVILLE TO MIAMI, FL. To be conservative, the latest three-year waterborne traffic data for these points, i.e., Calendar Years 1994, 1995, and 1996, are requested from the Waterborne Commerce Statistics Center. These points with three-year data, which have been selected according to the *Waterborne Commerce Of The United States 1997*, include the follows: 3, 4, 5, 6, 7, 9, 10, 11, 12, 14, 20, 21, 22, 28, 32, 33, 34, 35, 36, 37, 40, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, and 52.

A summary of points with one-year or three-year data is listed in Table 1.

3.2 VESSEL FLEET CHARACTERISTICS

After request for data of 52 past points has been accomplished by the Waterborne Commerce Statistics Center (WCSC), these points were processed and the results were carefully reviewed. It is found that most of them have reasonable data. However, a few points have only several lines of data record, such as point 38. In this case, the WCSC has been contacted to check the requested point location and its data again. Accordingly, point 38 was found to be a waterway that was a dead-end and probably has no through traffic.

The processed data format has been developed by FDOT. Therefore, every point processing follows this format. A FORTRAN program is written to process this data. When unreasonable data information is found, for example, 999.99 ft in width and 9999.99 ft in length in lines 3,4, and 7 of file ”ww1049.txt”, the information was replaced by the vessel with the same or close empty and loaded drafts and vessel type.

3.2.1 Tug and barges

Tug and barge(s) are usually operated together as a flotilla on waterways. Based on the WCSC’s data, it is impossible to judge the tug type correspondent to a specific barge train. To simplify the processed results, tugs operated on the Florida’s waterways are classified by FDOT into three types: small, medium, and large. Their sizes and capacities are shown in Table 2. The barge vessel traffic is classified by its draft and corresponding tug size is assigned to the loaded groups in Table 3.

In the process of synthesizing data, free tugs are found on some past points. In such a case, these free tugs are classified into one vessel group. In lieu of adopting the classified tug type in Table 2, a statistic of actual tug traffic information is made to reflect actual traffic.

3.2.2 Self-propelled Vessels:

Generally, self-propelled vessels on each past point are assigned into only one group. However, some points are found to have predominant self-propelled vessel traffic. According to the FDOT comments, these self-propelled vessels are sub-grouped according to their drafts. The assignment by the five-group method similar to barges classification has been tried, but the majority of self-propelled vessel trips has been found to fall into only one group, i.e., the sub-grouping generates little effects on the design results and appears to be not necessary. Therefore, the draft interval between vessel groups is decreased from 3 ft to 2 ft. In practice, it is found that this change generates a better vessel grouping result. Past points that encounter the sub-grouping include the follows: 06, 07, 09, 10, 11, 12, 14, 20, 22, 32, 37, 40, 42, 43, and 49.

In the case of determining collision force on pier, calculation formula for ships is different from that for barges. Information of ship's deadweight tonnage is needed to obtain ship collision force on pier. Typical ship characteristics listed in Tables 3.5.2-1, 3.5.2-2, and 3.5.2-1 of the *Guide Specification* (1991) are reviewed and the relationship between DWT and ship sizes is summarized (Detailed discussions refer to Section 5.2 BASIC INPUT DATA in the report).

3.2.3 Foreign Vessels

Approximately on ten points, foreign vessels have been found: 06, 07, 08, 13, 23, 25, 30, 36, and 39. Basically, these foreign vessels have been added into the same domestic vessel types by trips.

In the case of only foreign vessels in one vessel group, vessel size and displacement can not be obtained from the requested data. It is found through research that almost every foreign vessel has 2 ft lightdraft and 20 ft loaddraft, i.e., these vessels are identical. As a simplified method, the vessel size is determined according to typical vessels with similar lightdraft and loaddraft in Tables 3.5.2-1, 3.5.2-2 and 3.5.2-3 of the AASHTO *Guide specification and commentary for vessel collision design of highway bridges*(1991).

Width:

(41.7+42.0+43.3)/3 = 42.33 ft

Length:

(282+279+289)/3 = 283.33 ft

Total vessel and cargo *displacement* in tons is calculated as:

$$Length \times width \times 1.03 \times draft \times 63/2000 \text{ tons} \tag{6}$$

where

length = vessel overall length;

width = vessel overall width;

draft = draft of vessel at movement; and

1.03 = modification coefficient

3.3 SYNTHESIZING RESULTS

To synthesize the requested data, a FORTRAN program is written to process these data and obtain useful input information for the Design Method II. The latest data we can request from the WCSC are those of CY1996. Corresponding to the requirement of FDOT, data in CY2000 as the final results, which are transferred from those in CY1996, are listed in **Appendix III**.

3.3.1 One-year Data

The past points, on which one-year data are requested, include the following 20 points: 1, 2, 8, 13, 15, 16, 17, 18, 19, 23, 24, 25, 26, 27, 29, 30, 31, 38, 39, and 41. These points are determined by *Waterborne Commerce Of The United States 1997 parts 1 thru 5*. In the waterway areas, to which the 20 points belong, annual tonnage has shown slight variation in the recent ten years. Synthesized vessel characteristics are tabulated as shown in **Appendix III**. The definition of each column of the tables listed in **Appendix III** is explained as follows:

Column A: All kinds of vessels contained in the requested data are placed in groups by draft as shown in Table 3. In Florida waterways, these vessel types include barge train, tug, and self-propelled vessels.

Column B: Compute the weighted average draft for each group defined (weight value is the number of trips).

Column C: List the total number of barges in each group.

Column D: List the number of barges per trip. This number will be equal to the total number of barges divided by the total number of tug trips for a given direction. Some points have more tug trips than barge trips, thus an additional vessel group of free tugs is added to the total vessel groups.

Column E: Compute and list the number of barge train or self-propelled vessel trips for each vessel group.

Column F,G: Compute the weighted average width and length for each vessel group.

Column H: Compute the weighted average of actual displacement of single barge or self-propelled vessel based on Eq. (6).

Column I: Assign tugs to each barge group as shown in Table 3.

3.3.2 Three-year Data

The past points, on which three-year data are requested, include the following 32 points: 3, 4, 5, 6[a], 7[a], 9, 10[b], 11[b], 12[b], 14, 20, 21, 22, 28, 32, 33[c], 34[c], 35[c], 36, 37[d], 40[d], 42[e], 43[e], 44[f], 45[f], 46, 47[g], 48[g], 49, 50, 51[h], 52[h] (Past point numbers with the same letter “a” have the same or very close data; “b”, “c”, so on). These points are determined by *Waterborne Commerce Of The United States 1997 parts 1 thru 5*. In the waterway areas, to which the 32 points belong, annual tonnage has turned out to be significantly fluctuating in the recent ten years. Synthesized vessel characteristics are tabulated as shown in **Appendix III**. An average of three-year data is taken for every vessel group on every point.

3.4 FUTURE TRAFFIC PREDICTION

Relevant Department of the U. S. Army Corps of Engineers was contacted to inquire about the future waterborne traffic in Florida. It is found that no data for future waterborne traffic projection in Florida is available. Hence, the book *Waterborne Commerce Of The United States* 1997 has been employed to address the prediction of future waterborne traffic increase rate (See **Appendix II**). Fifty-two past points have been located in different waterway areas. Traffic increase rates in these areas have been predicted under the condition that a trend of straight line will be followed in the future. Some areas are found to have negative increase rates and some points are not located in these areas listed in the book. In these cases, the entire Florida tonnage increase is adopted for these points. In **Appendix II**, annual increase rate for CY2000 is listed for every waterway areas. In the project, it is assumed that vessel characteristics remain the same during the life expectation of bridges, and the possible future increase is reflected in the increase of vessel trips. The waterborne traffic for the year y after CY2000 can be predicted by the following formulation under the assumption of linear increase:

$$\textit{basic data} \times [1.0 + \textit{increase rate} \times (y - 2000)] \tag{7}$$

where

y = target year; and

basic data = CY2000's data

3.5 VESSEL TRANSIT SPEED

Vessel transit velocity varies with many factors including its power or the power of its tugboat, weather condition, traffic condition, channel characteristics (straight or curve), and its loading condition, etc. Therefore, it is onerous to gather accurate data for a particular bridge site from available database. Herein, one approximate approach is adopted to make an estimation of vessel transit velocity on waterways in Florida. In the book *Waterborne Transportation Lines of the United States (WTLUS), Calendar year 1995, volume 1 through 3*, vessel companies associated with Florida waterways have been reviewed and selected. Efforts have been made to obtain the information on transit velocity of the vessels operated on Florida's inland waterways. Acquired responses from these vessel companies are shown in Table 4. The obtained data are summarized in Table 5 and recommended vessel transit velocity is shown in Table 6. In Table 6, vessel operation condition and waterway channel condition are taken into account to classify the transit velocity in more detailed cases. According to the data provided by the U.S. Coast Guard, typical flotilla transit velocities are between 4 and 6 knots.

4. DATA VERIFICATION

The objective of this section is to make sure the synthesized results are reasonable. Two kinds of resources are available to verify the requested data from the WCSC: (1) Bridge tender logs maintained by FDOT; and (2) *Section 2 Trips and Drafts of Vessels* in the book *Waterborne Commerce Of The United States* 1997.

4.1 REQUEST FOR BRIDGE TENDER LOGS

Florida Department of Transportation maintains tender logs for every movable bridge in Florida. Totally, maintenance offices of seven FDOT districts have been contacted and bridge tender logs for points 04, 06, 09, 10, 14, 20, 34, 36, 37, 43, 45, 48, 50, and 52 have been requested. Requested results are summarized in Table 7.

4.2 DATA COMPARISON BETWEEN TENDER LOGS AND WCSC

Some bridge tender logs turn out to be not clear because they were sent either in the form of annual accumulation, or in the form of “Power”, “Trawler”, and “Fish”, instead of standard vessel types as “P”, “C”, “T”, and “G”. Finally, there are only a number of bridge tender logs available and useful, e.g., past the points 6, 20, 37, 43, and 52. Table 8 demonstrates the 1996 tug and barge trips from both bridge tender logs and the WCSC.

In Table 8, it can be found that vessel trips from bridge tender logs and the WCSC are generally not in good accordance, except a few cases. When bridge tender log for point 43 is processed, it is found that there are many local waterborne traffic, namely pleasure craft, which may not be included in the WCSC data. The two completely different approaches to acquire data account for the major reason why there is significant discrepancy between two data sources. Other reasons leading to the difference may include incorrect information given by tug/barge company to WCSC, the human assumption of flotilla combination, etc.

After the processing of requested data, it is found that traffic on some points contain primarily self-propelled vessels, e.g., points 37 and 43. Table 9 demonstrates a comparison of trips of tug and barge trains with trips of self-propelled vessels between tender logs and WCSC.

To investigate the specific vessel type that possesses the majority of self-propelled vessels, more detailed information on vessel types was requested from the WCSC. A summary of annual trips of points 6, 9, 11, 22, 36, 37, 43, 47, and 48 in CY1996 of self-propelled vessels is shown in Table 10. From Table 10, it is found that passenger vessel trips constitute most of the vessel traffic. These passenger vessels are the same as the pleasure crafts, which appear to be the majority of traffic in bridge tender logs. It has been determined at several sites that the predominant self-propelled vessel is one of the following: passenger, crew boat, or excursion.

4.3 DATA VERIFICATION WITH ANNUAL SUMMARY

The book *Waterborne Commerce of the United States (WCUS)* 1997 contains one part that summarize the annual vessel trips in various waterway areas in the U. S. In *Section 2*: *Trips and Drafts of Vessels*, the summary of annual trips of different vessels in various Florida areas has been carefully selected. All these areas have been selected and the areas with questionable points (i.e., points 05, 21, 28, 33, 34, 35, 36, 44, 45, 47, 48 and 50), which carry heavy self-propelled vessels, have been studied. Points 05, 28, 33, 34, 35, 36, 44, 45, 47, 48 and 50 are located in intracoastal waterway, Jacksonville to Miami, Florida and the summary demonstrates that annual upbound trip number of self propelled vessels is 2495 plus 531, i.e., 3026, while annual upbound trip number of non-self propelled vessels is 85 plus 288, i.e., 373 (see page 313). The former trip number is much larger than the latter. Point 21 does not belong to any area listed. However, it is connected with Ft Pierce harbor in Florida, through a long distance intracoastal waterway. In Ft Pierce harbor, similar results are found between self propelled and non-self propelled vessels, i.e., for upbound 202 to 5 (see page 317). For the downbound direction, a similar phenomenon is observed, too. Therefore, the annual summary provides us a verification for those requested data from the Waterborne Commerce Statistics Center (WCSC), which contain heavy self-propelled vessels.

5. DESIGN EXAMPLE

A numerical example is presented hereby to demonstrate the procedure of the AASHTO Design Method II and to examine the design results by using the requested data.

5.1 BRIDGE DESCRIPTION

The following vessel impact resistant design shown in Figure 3 is an illustrative example bridge, which is supposed to intersect the Indian River in Florida. The coordinates of this bridge site, i.e., past point # 3, are latitude 28°24’12” and longitude 80°43’54”. This location was selected as a past point to obtain waterborne traffic data from the WCSC. The vessel characteristics and annual trip frequency are classified into several groups on the basis of data requested from the WCSC. When requesting data in this project, it is informed that the latest data available from the WCSC are those of Calendar Year 1996. Because the annual traffic tonnage in this waterway varies significantly around CY1996 (*Waterborne Commerce of the United States* 1997), three-year data (i.e., 1994, 1995 and 1996) are requested and an average is taken for every vessel characteristic.

5.2 BASIC INPUT DATA

In the process of synthesizing vessel characteristics data, it is difficult to obtain the vessel displacement capacity because incomplete data records are sometimes encountered, especially in the case of foreign vessels. The WCSC database uses a large number to substitute any incomplete information, such as “999999”, “9999.9”, or “999.9”. Therefore, the vessel displacement capacity including self weight and cargo is approximately calculated by Eq. (6) according to the fact that buoyant objects displace an amount of water equal to their weight.

Other necessary data for collision risk analysis are assumed as follows:

1. This is a critical bridge and the corresponding acceptable risk of bridge collapse is 0.0001 (a return period is 1 in 10,000 years);
2. There are a total number of 14 piers on both sides of channel. Each bridge pier and its super structure approximately represent 1/14 of the replacement cost of the bridge. Hence, each pier will be apportioned about 7.14 percent of the total acceptable annual frequency 0.0001, i.e., the annual frequency of collapse for a pier would be around 7.14×10^{-6};
3. Navigation channel width is 125ft;
4. Locations of bridge piers, width of bridge piers, and water depth at these pier locations are shown in Table 11;
5. The design impact speeds for each vessel group are taken from Table 6; and
6. For the simplicity of calculation, tugs are classified into three groups and assigned to barge groups by barge draft at movement as shown in Table 3.

This bridge is designed in accordance with Method II prescribed in the AASHTO *Guide Specification* (1991). Since the waterway characteristics are not symmetric and upbound and downbound waterborne traffic are not the same, each direction traffic is taken separately to perform the risk analysis for the whole bridge structure. In the design practice, it is difficult to distribute the assigned annual frequency of collapse for each pier exactly to 7.14×10^{-6}. In this example, the annual frequency of collapse for each pier is adjusted to no more than 7.14×10^{-6}, the return period is 140056 years.

The AASHTO *Guide Specification* (1991) gives no guidance for the consideration of possible future barge traffic growth during the design life of the bridge. In the example, an increase rate of waterborne traffic tonnage in a 50-year period is predicted from the accumulated data listed in the Part I and Part II of *Waterborne Commerce of the United States* (1995, 1996, and 1997). The records for past point # 3 over the Indian River were reviewed and demonstrated in Figure 4. Due to the large diversity of annual traffic tonnage, a linear relationship, which best fits the annual short tons (2000 pounds) from CY1982 to CY1996, has been derived to indicate the increase rate. From this fitted result, the annual increase rate at this point is 0.0153 based on the CY2000. Under this growth rate, the possible traffic 50 years later, i.e., in the CY2050, will be $1+50 \times 0.0153 = 1.765$ times of the traffic in the CY2000. It is assumed that the vessel sizes and capacities are invariable, therefore, this tonnage growth is reflected by the increase of annual frequency of vessel trips.

When computing ship collision force, the deadweight tonnage of ships is needed (see *Guide Specification* Section 3.9). Similar to Eq. (6), it can be estimated by the following relationship:

$$DWT = 0.447 \times Length \times width \times fully\ loaded\ draft \times 63/2205 \text{ tonnes} \qquad (8)$$

where 0.447 = ratio of DWT (tonnes) divided by displacement (tonnes), in which displacement can be calculated by Eq. (6) without a modification coefficient of 1.03 .

A detailed explanation of the ratio in Eq. (8), 0.447, refers to Table 12. Table 12 provides a comparison of typical ship characteristics between deadweight tonnage below 20,000 DWT (in Tables 3.5.2-1, 3.5.2-2, and 3.5.2-3 of the *Guide Specification* (1991), unit: tonnes) and calculated results from Eq. (8). It is found that ratio of DWT divided by Eq. (6) without multiplying a modification coefficient 1.03 falls in the range between 0.349 to 0.511. An average, 0.447, is taken as a ratio of DWT divided by Eq. (6) without multiplying an modification coefficient 1.03. Ship's DWT is also computed by 0.447×Displacement, and displacement is defined in Eq. (6) without multiplying a modification coefficient 1.03. In **Appendix III**, these data are listed in Column (I) as design input data.

5.3 DESIGN SUMMARY

According to the design Method II procedure of AASHTO *Guide Specification* (1991), the annual frequency of collapse under a given set of lateral ultimate strength shown in Table 13 is examined by the MathCad software. The summation of annual frequency of collapse of each bridge pier due to all upbound and downbound traffic turns out to be less than the assigned frequency 7.14×10^{-6} as shown in Table 14. Figures 5 and 6 demonstrate the calculated upbound and downbound annual frequency of collapse due to different vessel groups, respectively. From Figures 5 and 6, it can be found that the annual frequency of collapse of each bridge pier is different under upbound and downbound traffic. For the whole structure, the total annual frequency of collapse is 3.604×10^{-5} (upbound) + 5.380×10^{-5} (downbound) = 8.984×10^{-5}, and the corresponding return period is $1/8.984\times10^{-5}$ = 11,131 years. The return period is more than 10,000 years, therefore the bridge strength is acceptable. The detailed design example for both upbound and downbound direction by MathCad software is shown in **Appendix IV**.

5.4 DISCUSSION OF SMALL SELF-PROPELLED VESSELS

The AASHTO *Guide Specification* (1991) is not applicable to special purpose vessels, wood, or fiberglass constructed vessels, ships smaller than 1,000 DWT, naval vessels, nor to recreational vessels (see *Section 3.2 Applicability of Specification*). From the processed data, it is found that in the cases of waterborne traffic dominated by the self-propelled vessels, these vessels are generally very small ships with DWT less than 1000 tonnes.

To further investigate the influence of these small ships in the impact resistant design, the data in the aforementioned example are utilized in the following analysis. Due to the difference in upbound and downbound traffic, self-propelled vessels with 522.73 DWT (upbound) and 1479.69 DWT (downbound) are investigated respectively. There are totally four cases studied: number of annual trips in CY2050 equals to 0, 6, 600, and 6000. Among these cases, no difference is observed from the upbound outputs (522.73 DWT) as shown in Table 15, while apparent difference is observed from the downbound outputs (1479.69 DWT) as shown in Table 16. Therefore, the participation of small ships with DWT much less than 1,000 does not lead to any difference in impact resistant design and can be neglected in engineering applications. This result conforms to the AASHTO *Guide Specification* (1991).

6. SUMMARIES AND RECOMMENDATIONS

6.1 SUMMARIES

In the AASHTO *Guide Specification* (1991), Design Method II is a more difficult approach to apply than Design Method I because it needs much more waterborne traffic data at the bridge site. The objective to establish a complete set of database of waterborne traffic in the entire state makes it more economical to perform vessel impact resistant bridge design. In this project, major efforts have focused on the request, synthesization, and verification of waterborne traffic on inland and intracoastal waterways within Florida.

To obtain waterborne traffic data all over Florida, the first step is to select certain discrete points to represent the whole inland and intracoastal waterways within the state. Waterborne traffic on any specific point can be interpolated from these selected points, namely past points. Totally, fifty-two past points are chosen and approved by FDOT. Most of these past points are distributed along the intracoastal waterway areas of Florida.

The fifty-two past points are sent to the NDC's Waterborne Commerce Statistics Center (WCSC) in New Orleans, Louisiana to request one-year waterborne traffic. Since some points are found to have significant change on annual tonnages around the CY1996, three-year data have been requested on these points and an average is taken for every vessel characteristic. All the data in CY1996 on every past point are transferred into the data in CY2000.

These requested data are verified by two ways: bridge tender logs and annual summary of waterborne traffic. Several past points, which are actually movable bridge sites, are selected by FDOT as examples to request tender logs. These points are located over all the seven districts of FDOT. It is found that the trip records from bridge tender logs are not in good accordance with requested data from the WCSC. This discrepancy is mainly caused by two completely different systems of collecting data. However, it is found that trip distribution of the requested data is similar with the annual summary from the *WCUS* (1997).

The phenomenon of predominant self-propelled vessels is found for a considerable number of past points in some South Florida areas. The majority of these self-propelled vessels is small size vessel: 65 ft in length, 20ft in width, and DWT less than 300. Detailed data of some typical points are requested from the WCSC. The type of most self-propelled vessels is one of the following: passenger vessel; crew boat; and excursion.

Generally, the design life span of highway bridges is 75 years. It is necessary to take into account the future increase of waterborne traffic. Since no specific future tonnage projection in Florida is available, the book, *Waterborne Commerce Of The United States* (1997), has been utilized to predict future waterborne traffic increase rate. Traffic increase rates in the areas with selected past points have been predicted by a straight trend line. In the cases of the areas with negative increase rates or the isolated past points, which do not belong to any areas listed in the book, the entire Florida tonnage increase rate is adopted for these points.

Vessel companies in association with Florida waterways have been contacted to obtain the information on transit velocity of the vessels operated on Florida's inland waterways. The obtained data are summarized and typical vessel transit velocity is recommended based on vessel operation condition and waterway channel condition. The recommended flotilla transit velocity is in accordance with the data provided by the U.S. Coast Guard.

In the present study, the procedure of barge collision resistant design according to the AASHTO *Guide Specification* (1991) is reviewed and required input data for Design Method II are summarized. On this basis, a design example with 14 bridge piers is provided by using the requested waterborne vessel traffic. Due to the difference of waterway traffic between upbound and downbound, the bridge is analyzed separately for both directions and a total annual frequency of collapse is summarized.

In the project, annual trip number of self-propelled vessels in small size on some past points in South Florida areas is found extremely large. Therefore, the influence of these small vessels on impact resistant design is investigated by using the MathCad Software. It is found that these small vessels with DWT less than 1000 turn out to have little effect on the bridge pier design.

6.2 RECOMMENDATIONS

In the course of requesting annual waterborne traffic data from the WCSC, it is found that annual traffic tonnage in some waterways might have significant fluctuations in the past ten years, especially in the intracoastal areas. In such situations, it is recommended that statistics of vessel characteristics be made on the basis of at least 3-year waterborne traffic data.

Under the assumption of linear increase model, future traffic projection in Florida’s inland and intracoastal waterways has been predicted based on their annual tonnage summary. In addition to the synthesized data, every past point has been given an increase rate in CY2000 and an approach is also suggested for the calculation of future traffic prediction in a specific year. Consequently, it is recommended that future traffic increase rate for a specific bridge site be chosen from the closest one among existing past points.

Various typical vessel transit speeds have been investigated from major vessel companies, which operate vessels on Florida’s waterways. It is recommended that vessel transit velocity be assigned by its type, operation condition, and the channel characteristics, on which it is operated.

The AASHTO *Guide Specification* (1991) provides the acceptable annual frequency of collapse for all bridge components that may encounter vessel collision. It is recommended that the failure probability be distributed to achieve a uniform risk level over all bridge components. In the case study, it is found that a number of piers close to the navigation centerline need much more ultimate horizontal strength than those piers far from the navigation centerline when a uniform risk is achieved over all the bridge piers. As a result, the construction cost by vessel impact resistant requirement may appear to be higher than that by structural requirements from strength and serviceability limit state. In this case, the risk distribution can be determined based on the discretion from bridge owner and designer.

In some South Florida areas, the predominant self-propelled vessels are generally in small size and with DWT less than 1000. According to the AASHTO *Guide Specification* (1991), the specifications are not applicable to ships smaller than 1000 DWT. As shown in the design example, it is recommended that these small vessels be neglected in impact resistant design.

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Table 1.
Summary of Past Points

Points with One-year Data	Points with Three-year Data
1, 2, 8, 13, 15, 16, 17, 18, 19, 23, 24, 25, 26, 27, 29, 30, 31, 38, 39, 41	3, 4, 5, 6[a], 7[a], 9, 10[b], 11[b], 12[b], 14, 20, 21, 22, 28, 32, 33[c], 34[c], 35[c], 36, 37[d], 40[d], 42[e], 43[e], 44[f], 45[f], 46, 47[g], 48[g], 49, 50, 51[h], 52[h]
Total number: 20	Total number: 32
Total past points = 52 Note: a. past point numbers with the same letter “a” have the same or very close data; “b”, “c”, so on.	

Table 2.
Tug Size and Displacement

Tug size	Draft (ft)	Displacement (ton)	Width (ft)	Length (ft)
SMALL	4	65	20	50
MED	7	130	30	100
MED	7	130	30	100
LARGE	9	220	35	120
LARGE	9	220	35	120

Table 3.

Barge Classification and Assigned Tug

Group No.	Draft	Tug
1	<=3 ft	SMALL
2	>3 ft <=6 ft	MED
3	>6 ft <=9 ft	MED
4	>9 ft <=12 ft	LARGE
5	>12 ft	LARGE

Table 4.

Raw Records of Phone Calls

Company	Principal Commodities Carried	Waterways between Which or on Which Operated	Vessel Transit Speed	Vessel Description
Afram Carriers, Inc. P.O. BOX Groves TX 77619 Phone: (713) 435-1000	Bagged food stuffs, military cargo	Pensacola, Port Canaveral	Barge: Canal 5 MPH Intracoastal 4-6 MPH	General cargo carrier
American barge and Boat Services, Inc. 5440 West Tyson Ave, Tampa, FL 33611 Phone: (813) 839-8441	Construction equipment and materials	Florida Gulf Coast to Brownsville, TX; Florida East Coast and Bahamas to Norfolk, VA	Barge: 2-3 knots Speed on river is faster than that in intracoastal waterway.	General Cargo Carrier; Deck Barge
Blessey Marine Services, Inc. P.O.Box 28212 Harahan LA 70183 Phone: (504) 734-1156	Petro chemicals, dirty oils	Intracoastal waterway (Texas to Florida)	Canal: Loaded barge 6.5MPH, Empty barge 8 MPH Intracoastal waterway is the same as canal.	Pushboat; Tugboat; Dry Covered Barge; Double Hull Tank Barge; Other Tank Barge
Callais & Loumiet Towing, Inc. 120 WEST 108 ST. CUT OFF LA 70345 Phone: (504) 632-5537	Towing	Brownsville, TX to Panama City, FL	River: Barge Average 5MPH, Range 1-7 MPH Intracoastal: Average 3-4 MPH, MAX6 MPH	Tugboat; Pushboat
Central Oil Co., Inc. 1001 Mccloskey Blvd. Tampa, FL 33605 Phone: (813) 651-3785 Transfer to: Bay Operation Office Phone: (813) 247-1552	Bunker C # 6 Oil and Diesel # 2 Oil	Tampa Bay	Barge: MAX 8 knots Ship: MAX 12 knots	Double Hull Tank Barge
Chatham Towing Company, Inc. P.O.Box 576 Savannah GA 31402 Phone: (912) 236-1331	Bunker C, Diesel, Gasoline, Etc.	Inland Waterway – Jacksonville, FL to Norfolk, VA	Tug & barge: 7MPH loaded, 8-9 MPH empty	Pushboat; Single Hull Tank Barge

To be continued

Continued

Coastal Tug and Barge, Inc. P.O.BOX 025500 Miami, FL 33102-5500 Phone: (305) 551-5200	Towing and Bulk Petroleum Products	Altantic Introcoastal Waterway; Okeechobee Waterway; Miami Harbor; Port Everglades; Palm Beach; Port Canaveral; Boca Grande; Tampa, FL	Barge: Average 5-8 MPH Intracoastal: 5-6 MPH Canal: 5-6 MPH Loaded and empty barges are almost in the same speed.	Pushboat; Tugboat; Single Hull Tank Barge; Double Hull Tank Barge; Other Tank Barge
Zdiamond Services Corp. P.O.Box 1286 Morgan City LA 70381 Phone: (504) 631-2187	Equipment/Towing	Inland Waterways, Gulf of Mexico From Brownsville, TX to Florida	Barge: Loaded 5 knots Empty 5.5 knots	Tugboat; Dry Open Barge; Deck Barge

Table 5.
Summary of Towboat and Barge Transit Velocity

On River & Good Operation Condition	≅ 6.4 knots
On Intracoastal Waterway or Canal & Average Operation Condition	≅ 5 knots

Note:

Good operation condition: straight waterway channel, empty barge, powerful towboat, clear traffic, and good weather, etc.;

Average operation condition: curve waterway channel, loaded barge, mid-class power towboat, crowded traffic, and/or bad weather, etc.;

Table 6.

Recommended Vessel Transit Velocity

Vessel Type	Operation Condition	Recommended Velocity (knot)
Barge/Tug Train	Straight Navigation Channel and Clear Traffic	7[A]
	Curve Navigation Channel and/or Crowded Traffic	6[A]
Self-propelled Vessel (majority: passenger vessels)	Straight Navigation Channel and Clear Traffic	10[A]
	Curve Navigation Channel and/or Crowded Traffic	8[A]
Free Tug	Straight Navigation Channel and Clear Traffic	10[A]
	Curve Navigation Channel and/or Crowded Traffic	8[A]

Note:

A. Vessel velocities presented in the table are for empty vessels operating on wide river or unrestricted channels. For other conditions, modify the values shown by following corrections:

1. For loaded barge/tug combinations reduce the velocity by one knot;
2. For loaded self-propelled vessels, the velocity remain the same;
3. For barge/tug combinations operating on narrow canals or restricted intracoastal waterways reduce the velocity by one knot; and
4. For self-propelled vessels operating on narrow canals or restricted intracoastal waterways reduce the velocity by two knots.
5. Annual mean water current velocity is taken as 0.4 knots. When involved in the current velocity, vessel transit velocity is 0.4 knots less for upbound direction and 0.4 knots more for downbound direction.

Table 7.
Summary of Requesting Tender Logs

District	Past Points[a]	Contact Person	TEL/FAX Number	Content	Result
1	**9**, **43**	Pepe Garcia Luis Juarbe	SC 542-6050 Fax (813) 744-8251 (813) 744-6050	Have contacted Pepe Garcia	Point 43 received (9/28/98) It is not in the standard format of vessel types, such as "P", "C", "T", and "G".
2	45	Bud Rosher	SC 862-7000 Fax (904) 961-7095	Agreed to send log for past point 45	Received (6/6/98)
7	**37**	Don Kapadia Brian Bennett	SC 512-1227 Fax SC 512-1233 (813) 570-5101 Fax SC 513-3050	Sent request for past point 37	Received (6/9/98) It can not be processed due to no standard vessel types as "P", "C", "T", and "G".
4	**6**, 34, 36, 48, 50	Ray Radman	SC 436-4167 Fax SC 436-4697	Will send monthly log if requested, said may have to pay because information would be 2000 pages for one pt. Per year.	Sent yearly log summary for pts 6, 34, 36, but no sub-category of vessel types
5	4, **20**, 52	Ronnie Kneale	SC 383-5252 Fax SC 383-5469	Requested logs for pts 52, 20	Received (5/21/98)
6	**10**, **14**	Susan Stamm Harvey Shone Legal Dept.	(305) 470-5355 (305) 470-5458 Fax (305) 470-5610	Told to contact legal department (305) 470-5435 Sent request letter/fax 6/2/98	Only pt 10 Received (7/01/98) It can not be processed due to no standard vessel types as "P", "C", "T", and "G".

Note: a. Past points in bold are strongly recommended by FDOT to check requested data.

Table 8.
Comparison between Tender Logs and WCSC

Past the Points	Bridge Number	Direction	Tug & Barge Trips by Tender Logs	Tug & Barge Trips by WCSC	Commercial Trips by Tender Logs	Commercial Trips by WCSC	Note
20	110063	Upbound	184	227	53	422	
		Downbound	182	227	45	422	
10	900047	Upbound	27	7	-	1532	can not be processed due to no standard vessel types as “P”, “C”, “T”, and “G”.
		Downbound	30	7	-	1532	
37	150049	Upbound	1 (from 7/1-12/31)	57	-	3566	can not be processed due to no standard vessel types as “P”, “C”, “T”, and “G”.
		Downbound	3 (from 7/1-12/31)	80	-	3566	
6	860034	Upbound	-	52	-	489	Only yearly log summary
		Downbound	-	73	-	490	
43	170021	Upbound	65 (from 1/1-6/30)	77	-	4808	
		Downbound	71 (from 1/1-6/30)	96	-	4808	

Note: UPBOUND: NORTH OR EAST; DOWNBOUND: SOUTH OR WEST

Table 9.
Requested Bridge Tender Logs

Past the Points (1)	Bridge Number (2)	Direction (3)	Tug & Barge Trips by Tender Logs (4)	Commercial Trips by Tender Logs (5)	Power Vessel Trips by Tender Logs (6)	Percentage of (4) Divided by (5) or (6) (7)	Note (8)
20	110063	Upbound	184	-	-	-	T/B trip number is similar to the WCSC data 227
		Downbound	182	-	-	-	T/B trip number is similar to the WCSC data 227
52	790172	Upbound	358	1285	-	27.9%	
		Downbound	354	1195	-	29.6%	
45	780074	Upbound	197	448	-	44.0%	
		Downbound	201	526	-	38.2%	
43	170021	Upbound	65 (from 1/1-6/30)	-	1409 (from 1/1-6/30)	1:22	
		Downbound	71 (from 1/1-6/30)	-	1409 (from 1/1-6/30)	1:20	

Note: UPBOUND: NORTH OR EAST; DOWNBOUND: SOUTH OR WEST

In addition, points 10 and 37 have not significant annual tug/barge trips. Point 10: upbound 27, downbound 30; Point 37: upbound 1 (from 7/1-12/31), downbound 3 (from 7/1-12/31).

Table 10.

Summary of Self-propelled Vessel Trips (1996)

Point		Passenger	Fish	Shellfish	Machinery	Foreign	Total Trips
6	Downbound	2+17+455+1+1+4+ = 480	-	-	-	10	490
6	Upbound	2+15+455+1+5 = 478	-	-	2	9	489
9	Downbound	187+206+48+504+1619+1379 +1 = 3944	0	0	1	-	3945
9	Upbound	187+206+48+504+1619+1379 = 3943	-	0	2	-	3945
11	Downbound	56+292+37+320+827 = 1532	0	0	-	-	1532
11	Upbound	56+292+37+320+827 = 1532	-	-	-	-	1532
22	Downbound	187+157+706+48+504+1619+1379+1 = 4601	0	0	1	-	4602
22	Upbound	187+0+706+48+504+1619+1379 = 4443	0	0	157+2 = 159	-	4602
37	Downbound	62+504+1619+1379+1 = 3565	-	-	1 (empty)		3566
37	Upbound	62+504+1619+1379 = 3564	0	-	2 (empty)		3566
43	Downbound	187+206+706+48+504+1619+1379+1 = 4650	0	0	157+1 = 158		4808
43	Upbound	187+206+706+48+504+1619+1379 = 4649	0	-	157+2 = 159		4808
36	Downbound	3+1+1+2 = 7	-	-	-	10	17
36	Upbound	2+1+4 = 7	-	-	2	9	18
47	Downbound	3+1+2 = 6	0	-	3	-	9
47	Upbound	4+1+1 = 6	0	-	6	-	12
48	Downbound	2+1+2 = 5	-	-	1	-	6
48	Upbound	3+1+1 = 5	-	-	4	-	9

Table 11.
Channel and Bridge Characteristics

Items	Pier 1	Pier 2	Pier 3	Pier 4	Pier 5	Pier 6	Pier 7	Pier 8	Pier 9	Pier10	Pier11	Pier12	Pier13	Pier14
Pier locations [a] (ft)	102	240	384	528	672	768	864	102	240	384	528	672	768	864
Pier width (ft)	30	40	40	40	40	40	40	30	40	40	40	40	40	40
Water depth at pier [b] (ft)	12	12	10	10	10	8	8	16	16	13	13	13	10	10

Note: a. It means the distance from the centerline of channel to the centerline of pier;

b. It means the distance from existing mudline to mean high water.

Table 12.
Summary of Relationship between Sizes and DWT of Typical Ships

Length (ft) (a)	Width (ft) (b)	Fully Loaded Draft (ft) (c)	DWT (tonne) (d)	Eq. (6)/1.03 (tonne) (e)	Ratio of (d) divided by (e) (f)	Note (g)
200	29.2	14.1	1000	2358	0.424	Bulk Carrier
289	41.7	22.3	3000	7696	0.390	Bulk Carrier
341	48.9	21.3	5000	10171	0.492	Bulk Carrier
459	61.4	26.6	10,000	21468	0.466	Bulk Carrier
515	70.5	29.5	15,000	30672	0.489	Bulk Carrier
558	77.8	31.5	20,000	39160	0.511	Bulk Carrier
187	30.8	13.8	1000	2276	0.439	Product Carrier/Tanker
279	42.0	19.4	3000	6510	0.461	Product Carrier/Tanker
335	48.2	22.6	5000	10450	0.479	Product Carrier/Tanker
456	62.3	26.6	10,000	21640	0.462	Product Carrier/Tanker
515	71.2	29.5	15,000	30976	0.484	Product Carrier/Tanker
561	78.1	32.2	20,000	40401	0.495	Product Carrier/Tanker
190	31.2	13.8	1000	2343	0.427	Freighter/Container
282	43.3	19.4	3000	6784	0.442	Freighter/Container
338	50.5	22.3	5000	10900	0.459	Freighter/Container
472	63.6	26.9	10,000	23124	0.433	Freighter/Container
617	84.3	30.8	16,000	45876	0.349	Freighter/Container
643	90.6	34.4	20,000	57387	0.349	Freighter/Container
					Average 0.447	

Note: 1 tonne = 2205 pounds

Table 13.
Lateral Ultimate Strength of Each Bridge Pier

Piers	Pier 1	Pier 2	Pier 3	Pier 4	Pier 5	Pier 6	Pier 7	Pier 8	Pier 9	Pier10	Pier11	Pier12	Pier13	Pier14
Ultimate Strength (kip)	3230	2960	2650	2250	1650	750	240	3230	2960	2680	2270	1750	850	230

Table 14.
Summation of Annual Frequency of Collapse

Items		Pier 1	Pier 2	Pier 3	Pier 4	Pier 5	Pier 6	Pier 7	Pier 8	Pier 9	Pier10	Pier11	Pier12	Pier13	Pier14
$SumAFc_j$ $(\times 10^{-6})$	Upbound	0.42	1.88	3.02	3.41	3.30	3.69	3.07	0.42	1.88	2.59	3.24	3.33	3.45	2.32
	Downbound	6.54	4.80	3.43	3.40	2.97	2.94	3.15	6.48	4.75	3.47	3.48	2.85	2.78	2.76
Sum $(\times 10^{-6})$		6.96	6.68	6.45	6.81	6.27	6.63	6.22	6.90	6.63	6.06	6.72	6.18	6.23	5.08

Table 15.
Role of Small Self-propelled Vessels in Design (Upbound)

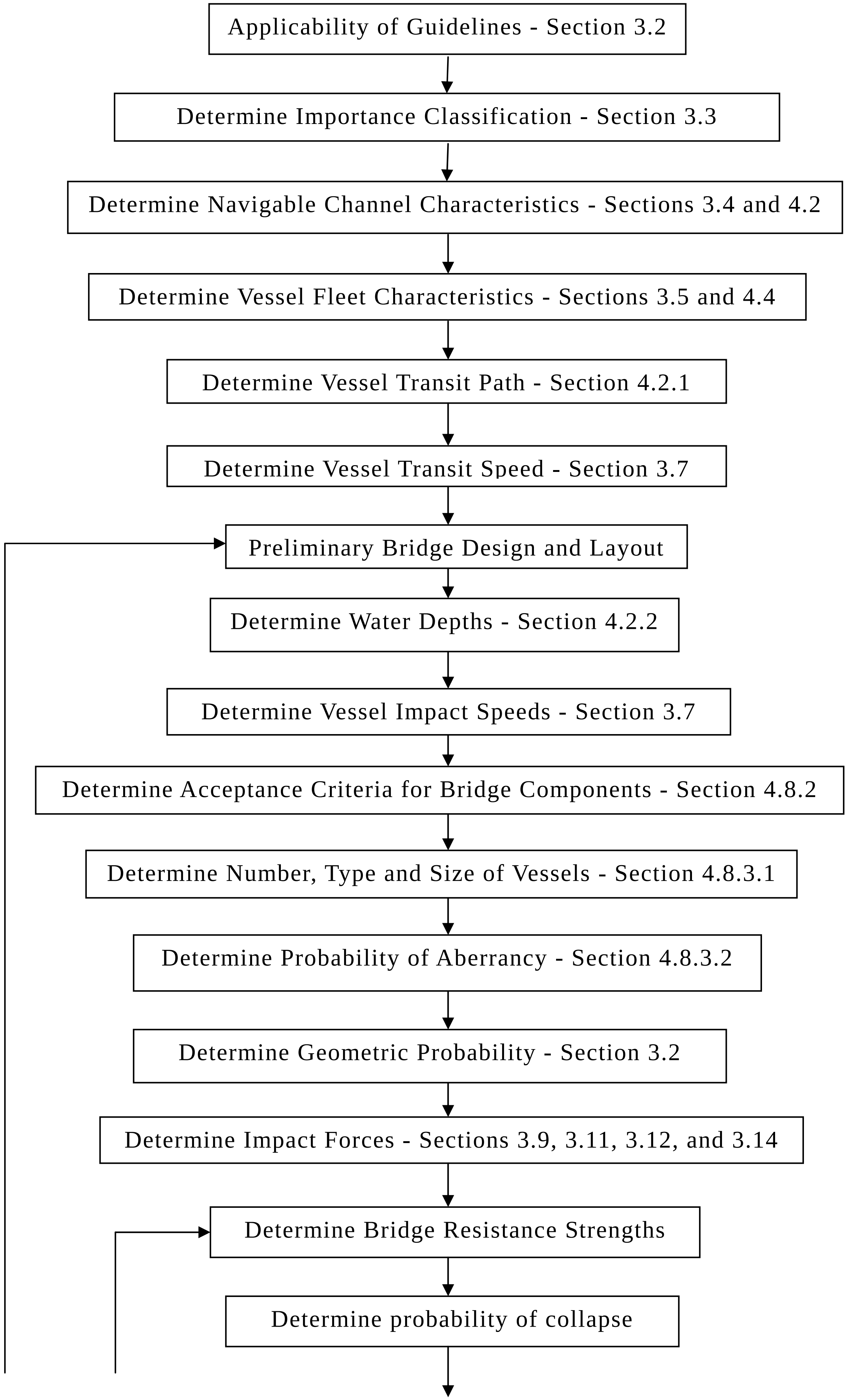
Number of Annual Trips in CY2050	N_i	x_j ft	B_{P_j} ft	H_j kip	$SumAFc_j$	$\%Risk_j$
0	37.59	102	30	3230	0.00000042	1.17
	33.22	240	40	2960	0.00000188	5.22
	8.15	384	40	2650	0.00000302	8.38
	18.18	528	40	2250	0.00000341	9.47
	49.51	672	40	1650	0.00000330	9.16
	0	768	40	750	0.00000369	10.24
		864	40	240	0.00000307	8.53
		102	30	3230	0.00000042	1.17
		240	40	2960	0.00000188	5.22
		384	40	2680	0.00000259	7.19
		528	40	2270	0.00000324	9
		672	40	1750	0.00000333	9.23
		768	40	850	0.00000345	9.57
		864	40	230	0.00000232	6.45
6	37.59	102	30	3230	0.00000042	1.17
	33.22	240	40	2960	0.00000188	5.22
	8.15	384	40	2650	0.00000302	8.38
	18.18	528	40	2250	0.00000341	9.47
	49.51	672	40	1650	0.00000330	9.16
	6	768	40	750	0.00000369	10.24
		864	40	240	0.00000307	8.53
		102	30	3230	0.00000042	1.17
		240	40	2960	0.00000188	5.22
		384	40	2680	0.00000259	7.19
		528	40	2270	0.00000324	9
		672	40	1750	0.00000333	9.23
		768	40	850	0.00000345	9.57
		864	40	230	0.00000232	6.45

	N_i	x_j (ft)	$B\ P_j$ (ft)	H_j (kip)	$SumAFc_j$	$\%Risk_j$
600	37.59	102	30	3230	0.00000042	1.17
	33.22	240	40	2960	0.00000188	5.22
	8.15	384	40	2650	0.00000302	8.38
	18.18	528	40	2250	0.00000341	9.47
	49.51	672	40	1650	0.00000330	9.16
	600	768	40	750	0.00000369	10.24
		864	40	240	0.00000307	8.53
		102	30	3230	0.00000042	1.17
		240	40	2960	0.00000188	5.22
		384	40	2680	0.00000259	7.19
		528	40	2270	0.00000324	9
		672	40	1750	0.00000333	9.23
		768	40	850	0.00000345	9.57
		864	40	230	0.00000232	6.45
6000	37.59	102	30	3230	0.00000042	1.17
	33.22	240	40	2960	0.00000188	5.22
	8.15	384	40	2650	0.00000302	8.38
	18.18	528	40	2250	0.00000341	9.47
	49.51	672	40	1650	0.00000330	9.16
	6000	768	40	750	0.00000369	10.24
		864	40	240	0.00000307	8.53
		102	30	3230	0.00000042	1.17
		240	40	2960	0.00000188	5.22
		384	40	2680	0.00000259	7.19
		528	40	2270	0.00000324	9
		672	40	1750	0.00000333	9.23
		768	40	850	0.00000345	9.57
		864	40	230	0.00000232	6.45

Table 16.
Role of Small Self-propelled Vessels in Design (Downbound)

Number of Annual Trips in CY2050	Design Summary					
	N_i	x_j (ft)	B_{P_j} (ft)	H_j (kip)	$SumAFc_j$	$\%Risk_j$
0	55.77	102	30	3230	0.00000376	8:02
	18.8	240	40	2960	0.00000412	8.79
	20.69	384	40	2650	0.00000343	7.32
	1.25	528	40	2250	0.00000340	7.24
	50.76	672	40	1650	0.00000297	6.34
	0	768	40	750	0.00000294	6.27
		864	40	240	0.00000315	6.71
		102	30	3230	0.00000371	7.91
		240	40	2960	0.00000408	8.7
		384	40	2680	0.00000347	7.4
		528	40	2270	0.00000348	7.42
		672	40	1750	0.00000285	6.08
		768	40	850	0.00000278	5.92
		864	40	230	0.00000276	5.89
6	55.77	102	30	3230	0.00000566	10.97
	18.8	240	40	2960	0.00000459	8.88
	20.69	384	40	2650	0.00000343	6.65
	1.25	528	40	2250	0.00000340	6.58
	50.76	672	40	1650	0.00000297	5.76
	6	768	40	750	0.00000294	5.7
		864	40	240	0.00000315	6.1
		102	30	3230	0.00000561	10.86
		240	40	2960	0.00000454	8.8
		384	40	2680	0.00000347	6.72
		528	40	2270	0.00000348	6.74
		672	40	1750	0.00000285	5.53
		768	40	850	0.00000278	5.38
		864	40	230	0.00000276	5.35

	N_i	x_j ft	B P_j ft	H_j kip	$SumAFc_j$	$\%Risk_j$
600	55.77	102	30	3230	0.00019360	37.31
	18.8	240	40	2960	0.00005031	9.69
	20.69	384	40	2650	0.00000343	0.66
	1.25	528	40	2250	0.00000340	0.65
	50.76	672	40	1650	0.00000297	0.57
	600	768	40	750	0.00000294	0.57
		864	40	240	0.00000315	0.61
		102	30	3230	0.00019354	37.3
		240	40	2960	0.00005026	9.69
		384	40	2680	0.00000347	0.67
		528	40	2270	0.00000348	0.67
		672	40	1750	0.00000285	0.55
		768	40	850	0.00000278	0.54
		864	40	230	0.00000276	0.53
6000	55.77	102	30	3230	0.00190211	39.9
	18.8	240	40	2960	0.00046594	9.77
	20.69	384	40	2650	0.00000343	0.07
	1.25	528	40	2250	0.00000340	0.07
	50.76	672	40	1650	0.00000297	0.06
	6000	768	40	750	0.00000294	0.06
		864	40	240	0.00000315	0.07
		102	30	3230	0.00190205	39.9
		240	40	2960	0.00046589	9.77
		384	40	2680	0.00000347	0.07
		528	40	2270	0.00000348	0.07
		672	40	1750	0.00000285	0.06
		768	40	850	0.00000278	0.06
		864	40	230	0.00000276	0.06


Applicability of Guidelines - Section 3.2
Determine Importance Classification - Section 3.3
Determine Navigable Channel Characteristics - Sections 3.4 and 4.2
Determine Vessel Fleet Characteristics - Sections 3.5 and 4.4
Determine Vessel Transit Path - Section 4.2.1
Determine Vessel Transit Speed - Section 3.7
Preliminary Bridge Design and Layout
Determine Water Depths - Section 4.2.2
Determine Vessel Impact Speeds - Section 3.7
Determine Acceptance Criteria for Bridge Components - Section 4.8.2
Determine Number, Type and Size of Vessels - Section 4.8.3.1
Determine Probability of Aberrancy - Section 4.8.3.2
Determine Geometric Probability - Section 3.2
Determine Impact Forces - Sections 3.9, 3.11, 3.12, and 3.14
Determine Bridge Resistance Strengths
Determine probability of collapse

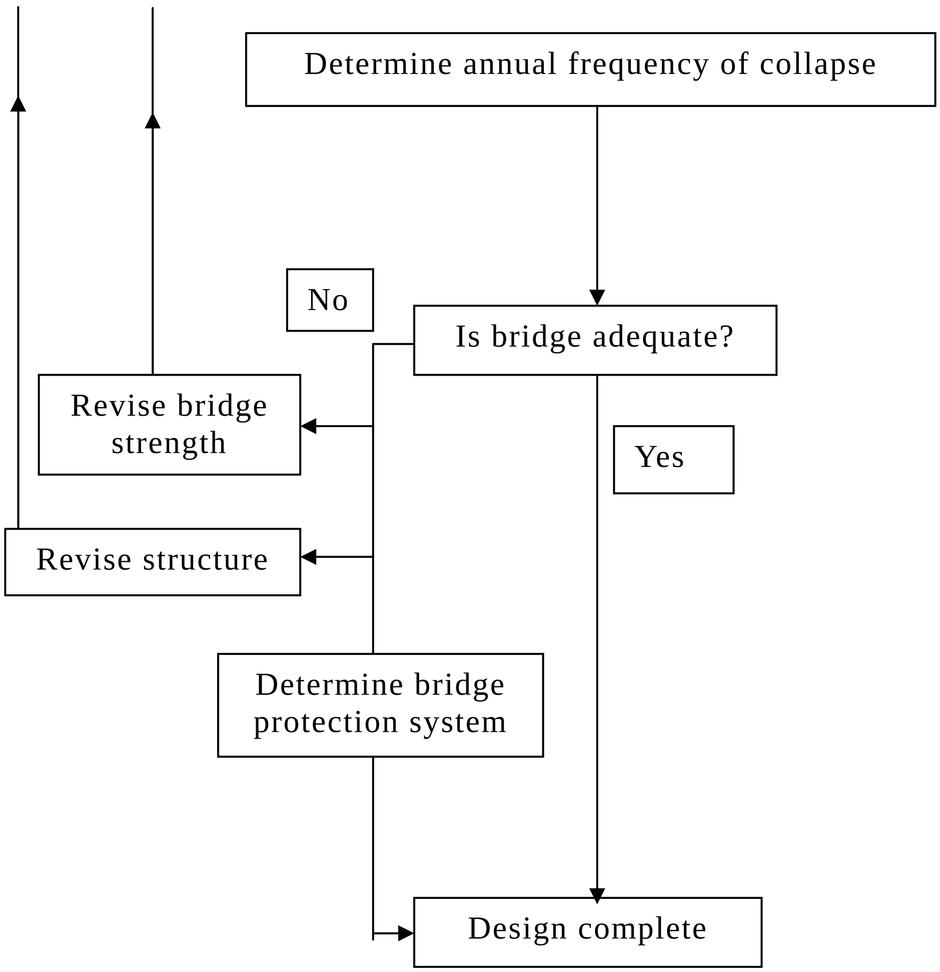
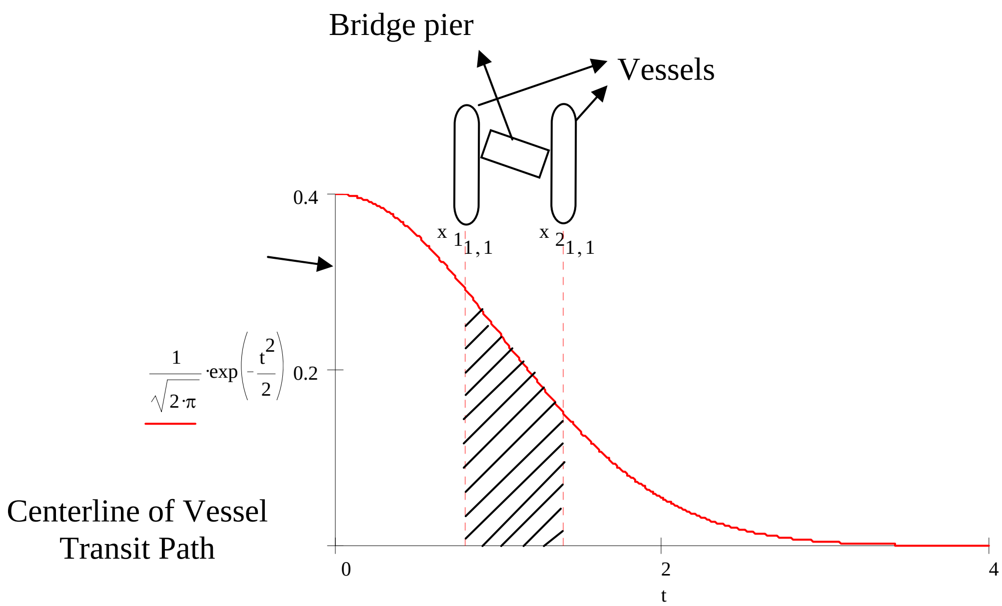


Figure 1. Flow Chart for AASHTO Design Method II



PG = Shadow area

Figure 2. Geometric Probability of Pier Collision

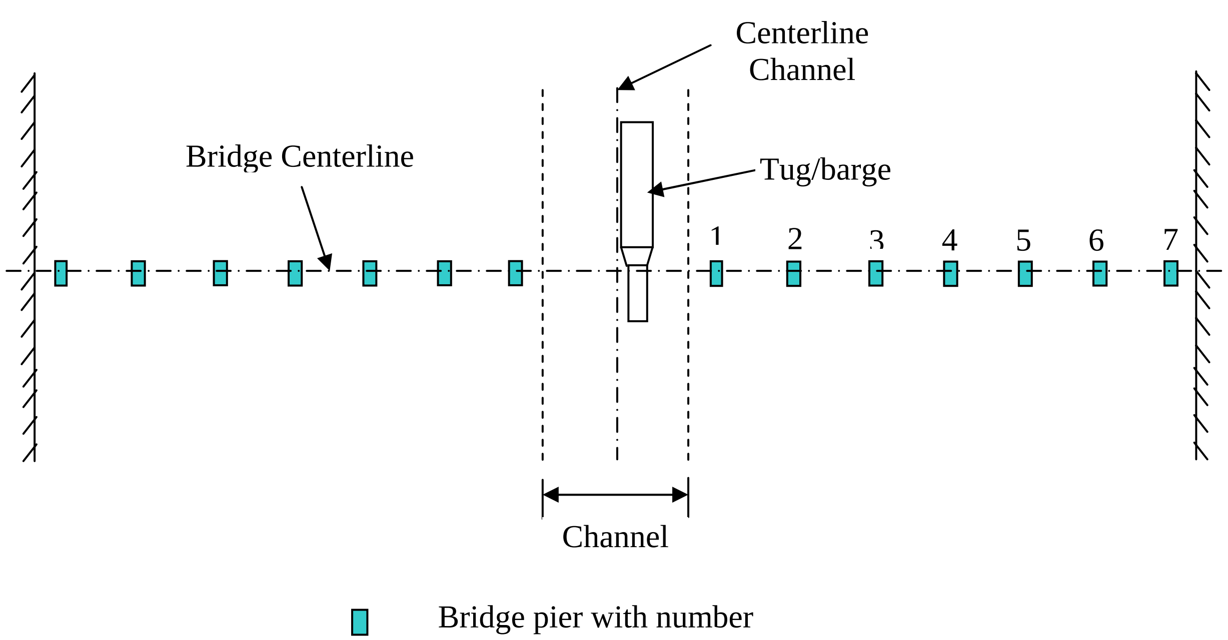


Figure 3. Plan of Waterway/Channel/Bridge Piers

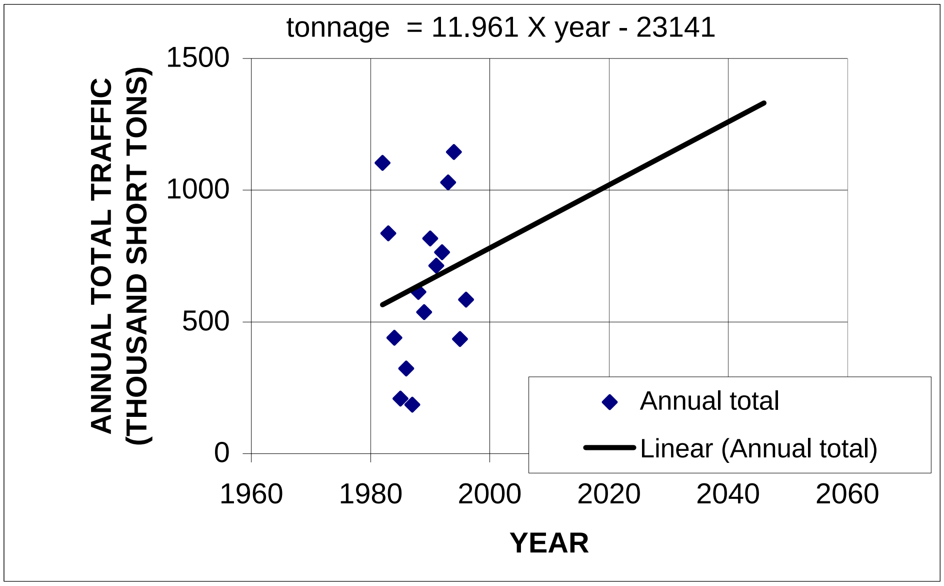


Figure 4. Future Traffic Tonnage Prediction

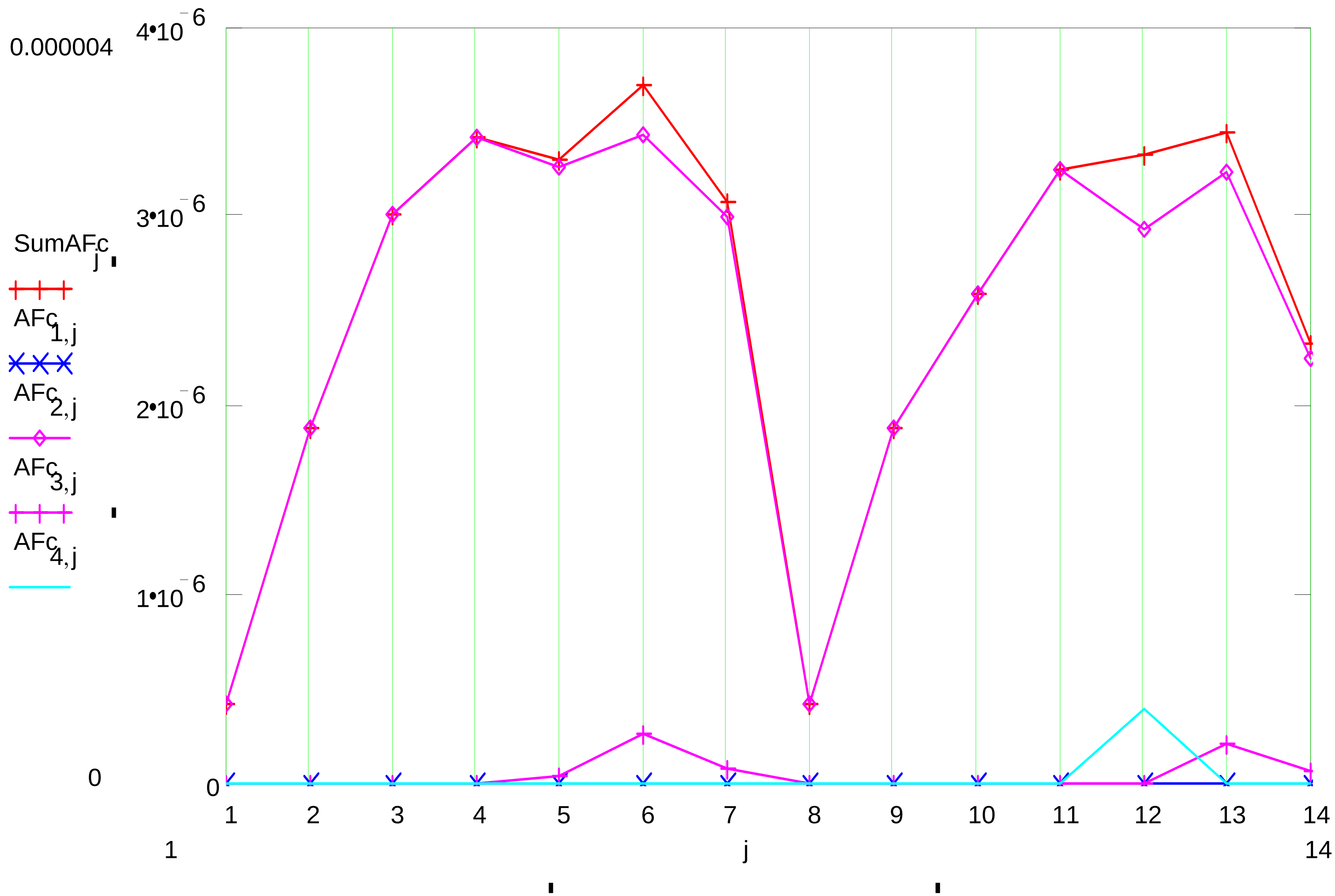


Figure 5. Annual Frequency of Collapse due to Upbound Vessel Group # 1, 2, 3, and 4

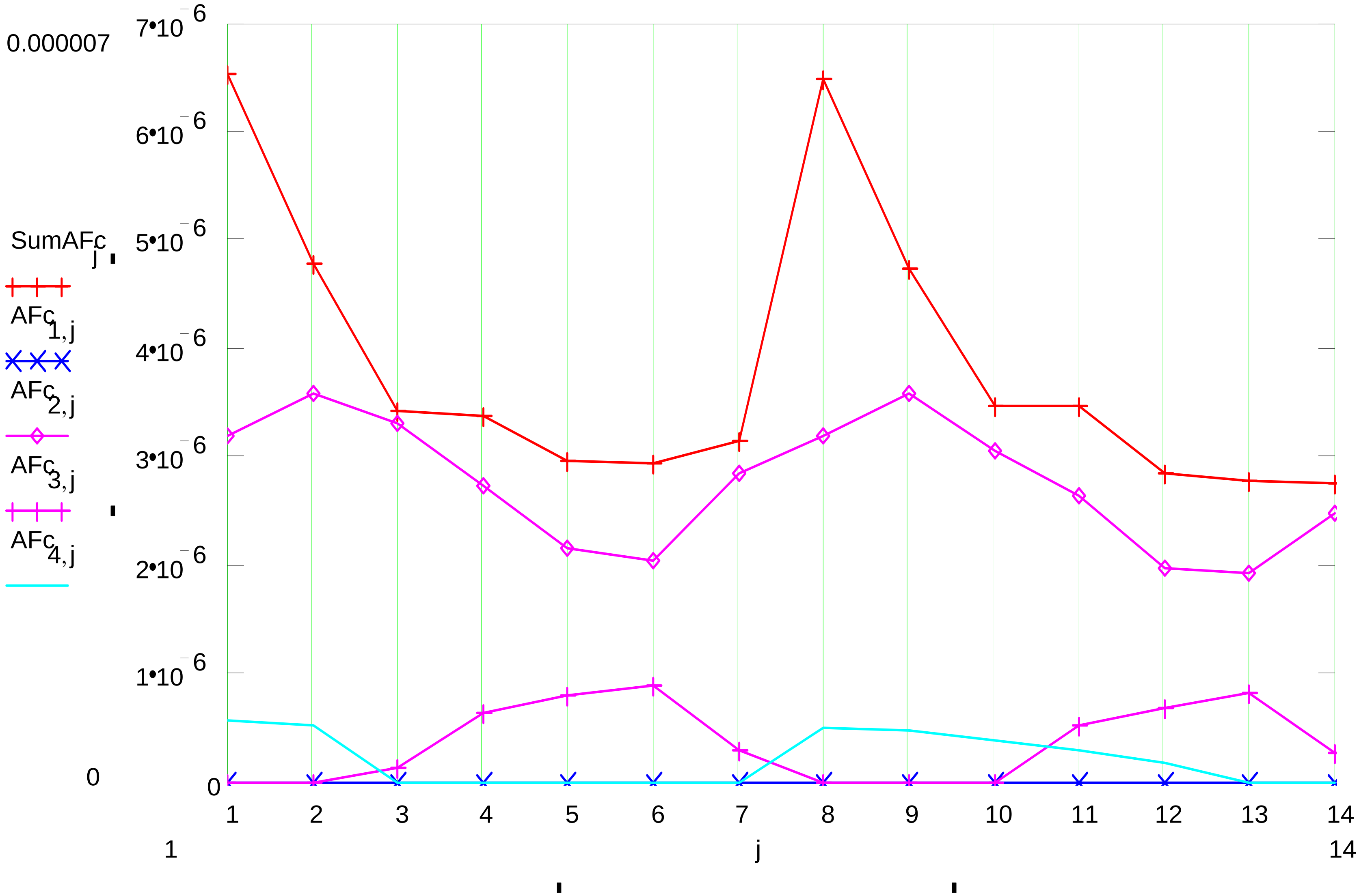


Figure 6. Annual Frequency of Collapse due to Downbound Vessel Group # 1, 2, 3, and 4

APPENDIX I

FIFTY-TWO PAST POINTS AND THEIR MAPS

PAST POINTS IN FLORIDA

According to the data entitled “Bridges with Navigation Control”, the total number of these bridges in Florida is 540. From these bridges, the past points in Florida has been selected and approved by FDOT. The basic ideas for the selection of past points are based on the following principles:

- Basically each major river/canal of every county possesses one past point;
- Bridge site of a moveable structural type is an optional past point.

As a result, a total number of 52 points has been chosen in the project as shown in Fig. I1 and Table I1. In Table I2, every bridge number with navigation control in Florida is sorted and assigned the past point to which it belongs. Some bridges do not belong to anyone of the 52 past points and they are listed in Table I3.

Table I1
Fifty-Two Past Points in Florida

NO	PAST POINTS	BRIDGE NO. WITHIN THE POINTS	COUNTY
1	LAT 30D 11’ 15” LONG 85D 44’ 12.1”	460012	Bay
2	LAT 30D 6’ 26.3” LONG 85D 36’ 20”	460019	Bay
3	LAT 28D 24’ 12” LONG 80D 43’ 54”	700016	Brevard
4	LAT 28D 24’ 12” LONG 80D 38’ 00”	700030	Brevard
5	LAT 28D 7’ 30” LONG 80D 37’ 30”	700184	Brevard
6	LAT 26D 0’ 36” LONG 80D 7’ 6”	860034	Broward
7	LAT 26D 11’ 24” LONG 80D 6’ 18”	860144	Broward
8	LAT 25D 56’ 54” LONG 80D 5’ 6”	860161	Broward
9	LAT 26D 56’ 6.1” LONG 82D 21’ 14.7”	010029	Charlotte
10	LAT 25D 11’ 0” LONG 80D 23’ 18”	900047	Monroe
11	LAT 24D 57’ 6” LONG 80D 35’ 30”	900077	Monroe
12	LAT 24D 50’ 24” LONG 80D 46’ 48”	900098	Monroe
13	LAT 25D 46’ 9.2” LONG 80D 11’ 52.8”	874262	Dade
14	LAT 25D 47’ 18” LONG 80D 10’ 42”	874459	Dade
15	LAT 29D 41’ 5.6” LONG 84D 52’ 32.2”	490003	Franklin
16	LAT 30D 37’ 43.3” LONG 84D 53’ 33.2”	500086	Gadsen
17	LAT 29D 52’ 46.9” LONG 85D 13’ 19.6”	510951	Gulf
18	LAT 29D 59’ 51.2” LONG 85D 22’ 13”	510048	Gulf
19	LAT 27D 56’ 36” LONG 82D 27’ 30”	100100	Hillsborough

20	LAT 29D 1’ 0” LONG 81D 23’ 0”	110063 St. Johns	Lake
21	LAT 26D 33’ 42” LONG 81D 56’ 0”	124044	Lee
22	LAT 27D 32’ 6” LONG 82D 39’ 36”	130054	Manatee
23	LAT 30D 19’ 18” LONG 81D 39’ 24”	720022	Duval
24	LAT 30D 23’ 48” LONG 81D 27’ 30”	720061	Duval
25	LAT 30D 23’ 40.5” LONG 87D 11’ 3.5”	480035	Escambia
26	LAT 30D 18’ 47” LONG 87D 25’ 35.1”	480118	Escambia
27	LAT 30D 22’ 9.6” LONG 87D 9’ 25.1”	480139	Escambia
28	LAT 29D 34’ 0” LONG 81D 11’ 0”	734071	Flagler
29	LAT 30D 30’ 48” LONG 81D 27’ 0”	740055	Nassau
30	LAT 30D 37’ 30” LONG 81D 28’ 48”	740088	Nassau
31	LAT 30D 25’ 57.5” LONG 86D 25’ 4.1”	570091	Okaloosa
32	LAT 26D 50’ 00” LONG 81D 5’ 30”	050044	Glades
33	LAT 26D 43’ 5.58” LONG 80D 2’ 36.37”	930157	Palm Beach
34	LAT 26D 49’ 55.69” LONG 80D 3’ 36.71”	930004	Palm Beach
35	LAT 26D 56’ 45.68” LONG 80D 5’ 4.82”	930005	Palm Beach
36	LAT 26D 20’ 23.08” LONG 80D 4’ 19.44”	930060	Palm Beach
37	LAT 27D 41’ 30” LONG 82D 43’ 0”	150049	Pinellas
38	LAT 27D 55’ 0” LONG 82D 36’ 54”	150107	Pinellas
39	LAT 27D 37’ 15.3” LONG 82D 39’ 20.2”	150189	Pinellas
40	LAT 27D 55’ 0” LONG 82D 50’ 0”	150068	Pinellas
41	LAT 29D 38’ 42” LONG 81D 37’ 30”	760043	Putnam
42	LAT 27D 10’ 48”	170064	Sarasota

	LONG 82D 29’ 42.9”		
43	LAT 27D 22’ 30” LONG 82D 31’ 36”	170021	Sarasota
44	LAT 30D 8’ 0” LONG 81D 23’ 6”	783080	St Johns
45	LAT 29D 53’ 30” LONG 81D 18’ 24”	780074 Atlantic Ocean	St Johns
46	LAT 29D 58’ 48” LONG 81D 37’ 42”	780056 St. Johns	St Johns
47	LAT 27D 27’ 35.04” LONG 80D 18’ 53.65	940094	St. Lucie
48	LAT 27D 28’ 21.76” LONG 80D 19’ 21.17”	940045	St. Lucie
49	LAT 27D 12’ 12.43” LONG 80D 15’ 40.65”	890003	Martin
50	LAT 27D 12’ 21.21” LONG 80D 11’ 38.67”	890060	Martin
51	LAT 29D 12’ 34.4” LONG 81D 0’ 42”	794003	Volusia
52	LAT 29D 20’ 20” LONG 80D 54’ 30”	790172 Atlantic Ocean	Volusia

Table I2
Bridge Number With Assigned Past Point

BRIDGE NO.	ASSIGNED PAST POINT
BAY	
460012	1
460019	2
460053	2
460077	1
460940	1
BREVARD	
700016	3
700028	4
700030	4
700031	4
700061	3
700069	4
700072	3
700077	5
700081	5
700110	3
700112	3
700115	3
700117	4
700137	3
700143	5
700147	5
700174	5
700181	5
700184	5
700201	3
703001	3
703002	3
703003	4
703004	3
704011	4
704015	4
704049	3
704063	5
BROWARD	
860001	8
860002	8
860008	8
860011	7
860018	6

860024	6
860034	6
860035	6
860038	8
860043	6
860060	7
860061	6
860063	8
860109	8
860144	7
860146	7
860152	7
860157	7
860160	6
860161	6
860209	8
860213	8
860222	7
860230	6
860259	7
860275	7
860278	7
860284	8
860319	8
860427	8
860428	8
860429	8
860430	8
860431	8
860466	6
860467	6
860546	8
860591	8
860592	8
860920	6
860941	7
864028	8
864071	8
864072	8
865748	8
CALHOUN	
470029	16
CHARLOTTE	
010029	9
010035	9

010050	9
010057	9
010058	9
010092	9
CLAY	
710006	23
710009	23
710011	23
710028	23
710045	23
710049	23
710050	23
710058	23
710059	23
DADE	
870071	14
870077	13
870082	14
870085	14
870147	13
870298	13
870301	13
870302	13
870356	13
870453	13
870479	13
870551	14
870554	14
870592	14
870593	14
870606	14
870607	14
870613	14
870658	14
870659	13
870660	13
870661	13
870662	13
870731	13
870759	13
870763	13
870772	13
870799	14
873002	14
874002	13

874129	13
874130	13
874134	13
874135	13
874161	13
874262	13
874383	13
874459	14
874474	14
874544	14
874545	14
874663	14
874664	14
874998	14
875000	14
875001	14
875101	14
875103	14
876100	14
876414	14
876705	14
876708	14
876714	14
DUVAL	
720005	23
720006	23
720011	23
720012	24
720014	24
720016	23
720022	23
720027	23
720032	23
720033	23
720042	23
720043	23
720044	24
720052	23
720053	23
720056	24
720057	24
720059	24
720060	24
720061	24
720062	24

720064	23
720066	23
720068	24
720069	24
720070	24
720073	24
720076	23
720077	24
720095	24
720107	23
720109	23
720110	23
720146	24
720149	23
720156	23
720184	23
720218	24
720249	23
720264	23
720271	23
720272	23
720280	23
720281	23
720325	23
720326	23
720336	24
720343	23
720352	23
720366	24
720370	23
720371	23
720425	23
720428	23
720435	23
720442	24
720443	24
720444	24
720445	24
720456	23
720457	23
720473	24
720474	24
720475	23
720476	23
720509	24

720514	24
720518	23
720550	24
720568	24
720569	24
720570	23
720571	23
720933	24
720934	24
720940	23
720941	23
724159	23
724214	23
724275	23
724279	23
724308	23
ESCAMBIA	
480001	26
480035	25
480037	25
480045	25
480118	26
480123	27
480136	25
480137	25
480139	27
480140	26
FLAGLER	
734061	28
734062	28
734063	28
734064	28
734071	28
FRANKLIN	
490003	15
490004	15
490023	15
490031	15
490034	15
GADSDEN	
500086	16
500087	16
GLADES	
050044	32
GULF	

510048	18
510052	17
510951	17
HENDRY	
070013	32
070033	32
HIGHLANDS	
090016	32
HILLSBOROUGH	
100039	22
100045	19
100049	19
100068	19
100100	19
100104	22
100107	19
100135	19
100136	19
100299	19
100300	19
100301	19
100332	19
100333	19
100338	19
100352	19
100353	19
100358	19
100359	19
100500	19
100585	19
100920	19
105500	19
105501	19
105502	19
105503	19
105504	19
105602	19
105604	19
105606	19
INDIAN RIVER	
880005	48
880053	48
880077	48
880087	48
884028	48

JACKSON	
530951	16
LAKE	
110007	20
110056	20
110063	20
110077	20
114079	20
LEE	
120002	21
120022	21
120028	21
120042	21
120050	21
120064	21
120083	21
120084	21
120088	21
120157	21
120158	21
124041	21
124043	21
124044	21
124065	21
126500	21
LEON	
550111	32
MANATEE	
130006	22
130053	22
130054	22
130057	22
130103	22
130104	22
130132	22
MARTIN	
890002	50
890003	49
890005	50
890016	49
890038	49
890058	50
890060	50
890066	50
890093	50

890103	50
890107	49
890120	50
890132	50
890133	50
890134	50
890135	50
890143	50
894044	49
MONROE	
900016	12
900045	12
900047	10
900077	11
900078	12
900094	12
900095	12
900096	12
900097	12
900098	12
900101	12
900103	12
900104	12
900106	12
900116	12
900117	12
900127	12
904025	12
904320	12
904490	12
904600	12
904603	12
904604	12
904606	12
904990	12
NASSAU	
740008	30
740018	30
740031	30
740055	29
740070	29
740081	29
740082	29
740087	30
740088	30

740089	30
OKALOOSA	
570017	31
570018	31
570034	31
570054	31
570082	31
570091	31
OKEECHOBEE	
910001	32
910009	32
910054	32
ORANGE	
755100	51
PALM BEACH	
930003	34
930004	34
930005	35
930007	35
930022	33
930026	36
930042	34
930056	35
930060	36
930064	36
930094	33
930097	33
930104	33
930105	36
930106	34
930154	36
930157	33
930214	36
930226	36
930269	33
930318	33
930322	36
930339	35
930349	34
930411	33
934408	36
934908	36
PASCO	
140005	40
PINELLAS	

150001	40
150006	40
150027	40
150028	40
150030	37
150038	39
150044	40
150048	37
150049	37
150050	37
150052	37
150068	40
150074	40
150076	40
150107	38
150112	40
150135	37
150181	39
150182	39
150189	39
150201	37
150210	38
150211	39
150213	39
150214	39
154000	40
154199	40
154209	40
154259	38
154260	38
154355	40
155502	40
155522	40
157191	38
157501	40
157800	37
PUTNAM	
760002	41
760035	41
760043	41
760044	41
760045	41
760046	41
SANTA ROSA	
580058	25

580071	25
580098	26
580167	26
580951	26
SARASOTA	
170021	43
170036	42
170052	43
170054	42
170057	42
170058	42
170061	43
170064	42
170065	43
170142	42
170158	43
170910	42
SEMINOLE	
770070	20
ST. JOHNS	
780003	45
780009	46
780042	46
780055	46
780056	46
780062	45
780074	45
780075	45
780076	45
780077	45
780089	45
780090	45
780097	45
780098	46
780099	45
780920	45
783080	44
ST. LUCIE	
940009	47
940045	48
940046	48
940094	47
940139	48
940144	48
944011	48

TAYLOR	
380087	15
VOLUSIA	
790030	46
790098	51
790124	46
790132	51
790139	51
790148	51
790152	52
790172	52
790940	46
794003	51
794004	51
794016	51
794025	51
WALTON	
600108	31

Table I3
Unsorted Bridge Numbers

Bridge NO.	County
020001	Citrus
030148	Collier
030184	Collier
290083	Columbia
290030	Columbia
300031	Dixie
300061	Dixie
310007	Gilchrist
050044	Glades
320016	Hamilton
320019	Hamilton
070013	Hendry
070033	
090016	Highlands
330009	LAFAYETTE
330027	
550111	Leon
350037	Madison
350054	Madison
350062	Madison
350001 Aurilla River	Madison
360055	Marion
364110	
364140	
364040	
910009	Okeechobee
910001	
910054	
370018	Suwannee
370023	Suwannee
370030	Suwannee
590016	Wakulla
610062	Washington
610047	

APPENDIX II

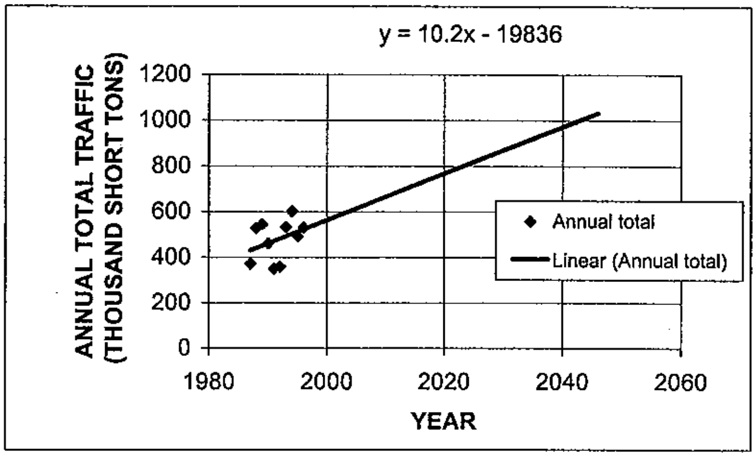
COMPETITIVE STATEMENT OF TRAFFIC AND PREDICTION OF FUTURE TRAFFIC INCREASE

Appendix II
COMPETITIVE STATEMENT OF TRAFFIC AND PREDICTION OF FUTURE TRAFFIC

ATLANTIC INTRACOASTAL WATERWAY BETWEEN NORFOLK, VA, AND THE ST. JOHNS RIVER (JACKSONVILLE DISTRICT)
Past the points: 30

Year	Annual total
1987	372
1988	527
1989	545
1990	461
1991	351
1992	359
1993	532
1994	602
1995	492
1996	530

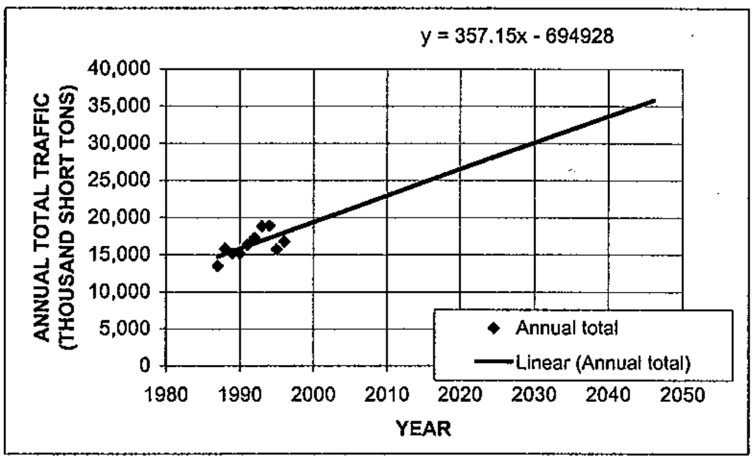
One Year Period Increase Rate
Based on 1 CY2000
0.0181



JACKSONVILLE HARBOR, FL
Past the points: 23, 24

Year	Annual total
1987	13,497
1988	15,823
1989	15,185
1990	15,120
1991	16,364
1992	17,209
1993	18,850
1994	18,914
1995	15,693
1996	16,737

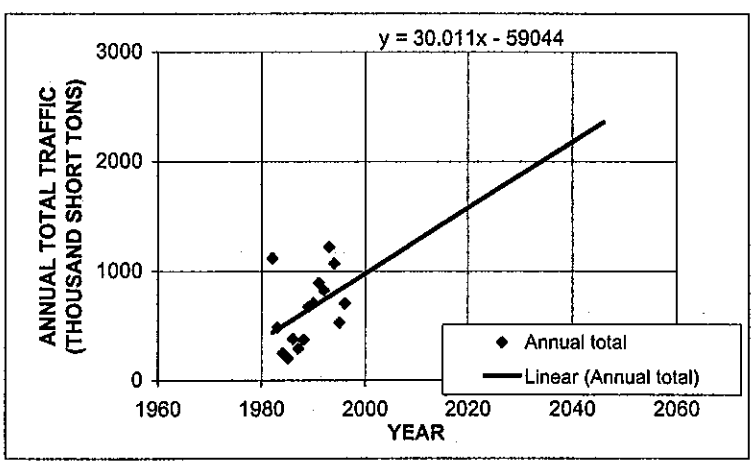
One Year Period Increase Rate
Based on 1 CY2000
0.0184



ST. JOHNS RIVER, FL JACKSONVILLE TO LAKE HARNEY
Past the points: 20, 41, 46

Year	Annual total
1982	1118
1983	482
1984	248
1985	202
1986	379
1987	291
1988	373
1989	673
1990	707
1991	891
1992	823
1993	1,220
1994	1,068
1995	527
1996	703

One Year Period Increase Rate
Based on 1 CY2000
0.031

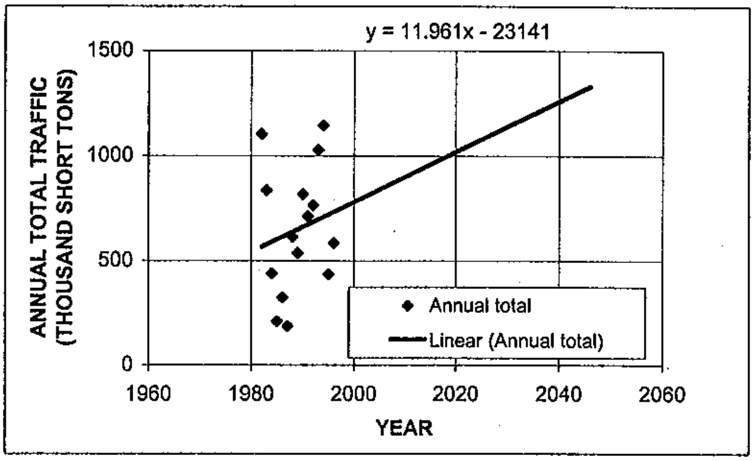


Appendix II
COMPETITIVE STATEMENT OF TRAFFIC AND PREDICTION OF FUTURE TRAFFIC

INTRACOASTAL WATERWAY, JACKSONVILLE TO MIAMI, FL
Past the points: 3, 5, 6, 7, 14, 28, 33, 34, 35, 36, 44, 45, 47, 48, 50, 51, 52+A243+A335

Year	Annual total
1982	1104
1983	836
1984	440
1985	209
1986	323
1987	186
1988	614
1989	537
1990	817
1991	713
1992	765
1993	1,029
1994	1,145
1995	435
1996	585

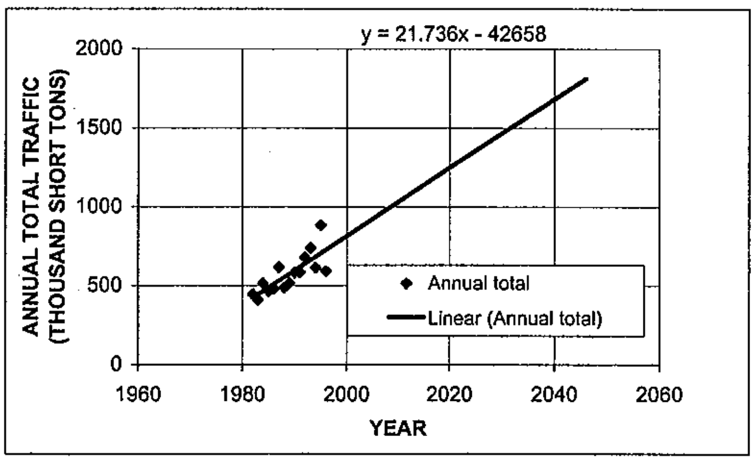
One Year Period Increase Rate
Based on 1CY2000
0.0153



MIAMI RIVER, FL (INCLUDED IN TRAFFIC OF MIAMI HARBOR, FL)
Past the points: 13

Year	Annual total
1982	446
1983	412
1984	514
1985	466
1986	481
1987	617
1988	489
1989	517
1990	582
1991	586
1992	680
1993	739
1994	615
1995	884
1996	593

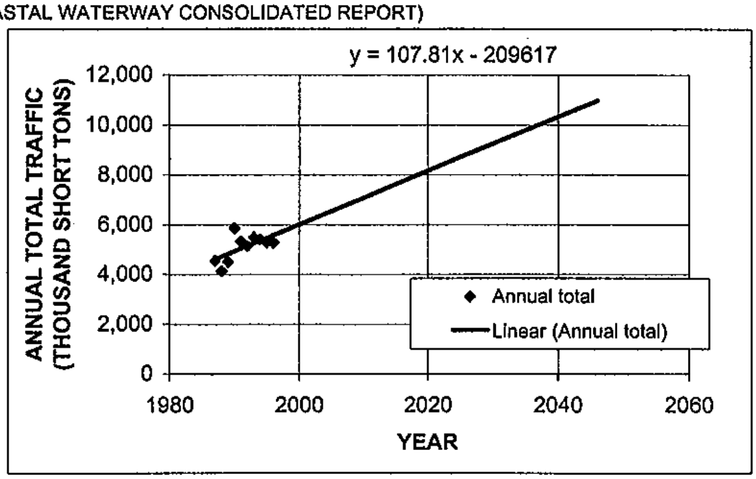
One Year Period Increase Rate
Based on 1CY2000
0.0267



GULF INTRACOASTAL WATERWAY, APALACHEE BAY TO PANAMA CITY, FL
(INCLUDED IN GULF INTRACOASTAL WATERWAY CONSOLIDATED REPORT)
Past the points: 2, 17, 18

Year	Annual total
1987	4,538
1988	4,134
1989	4,499
1990	5,855
1991	5,312
1992	5,150
1993	5,476
1994	5,399
1995	5,273
1996	5,273

One Year Period Increase Rate
Based on 1CY2000
0.018

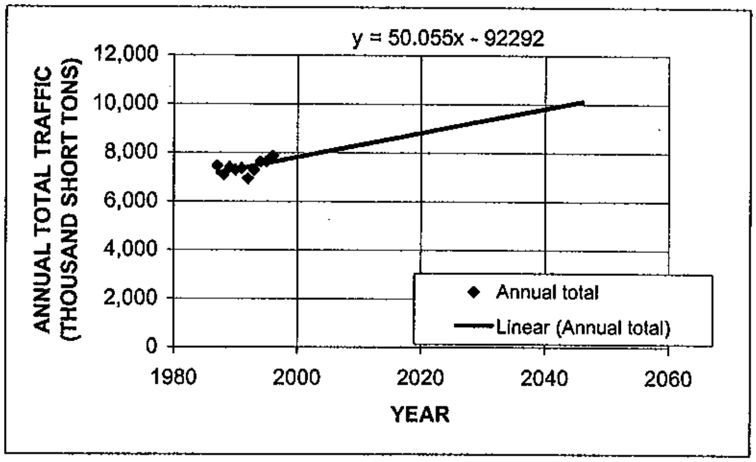


Appendix II
COMPETITIVE STATEMENT OF TRAFFIC AND PREDICTION OF FUTURE TRAFFIC

GULF INTRACOASTAL WATERWAY, PANAMA CITY TO PENSACOLA BAY, FL
(INCLUDED IN GULF INTRACOASTAL WATERWAY CONSOLIDATED REPORT)
Past the points: 1, 27, 31

Year	Annual total
1987	7,448
1988	7,089
1989	7,401
1990	7,295
1991	7,348
1992	6,933
1993	7,275
1994	7,619
1995	7,650
1996	7,861

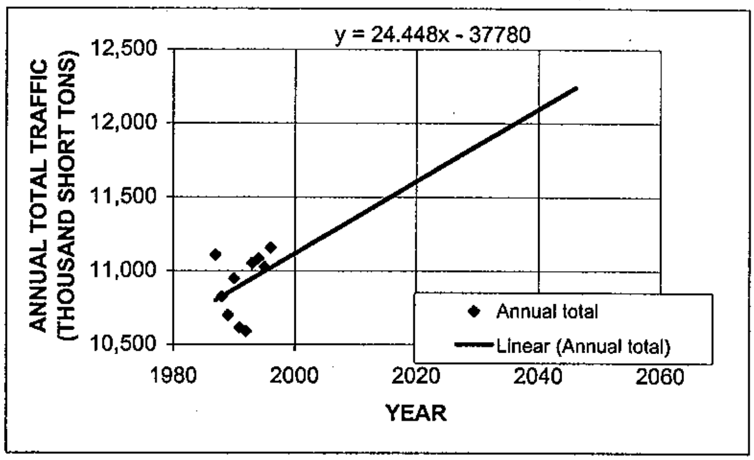
One Year Period Increase Rate
Based on 1 CY2000
0.0064



GULF INTRACOASTAL WATERWAY, PENSACOLA BAY, FL TO MOBILE BAY, AL
(INCLUDED IN GULF INTRACOASTAL WATERWAY CONSOLIDATED REPORT)
Past the points: 26

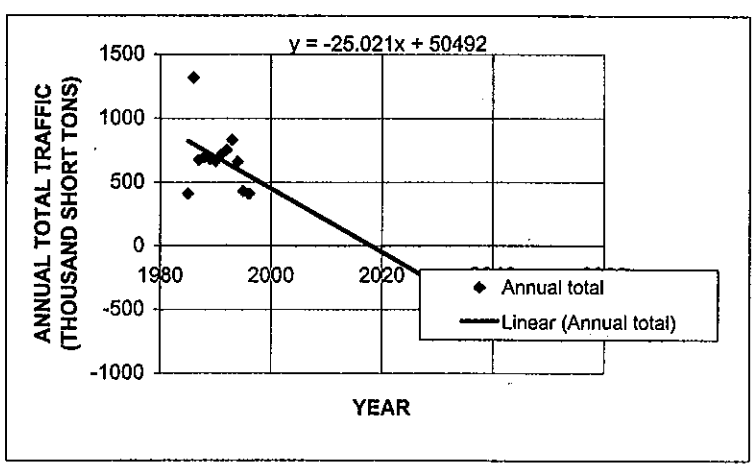
Year	Annual total
1987	11,107
1988	10,826
1989	10,699
1990	10,947
1991	10,613
1992	10,588
1993	11,052
1994	11,081
1995	11,025
1996	11,156

One Year Period Increase Rate
Based on 1 CY2000
0.0022



OKEECHOBEE WATERWAY, FL
Past the points: 21, 32, 49

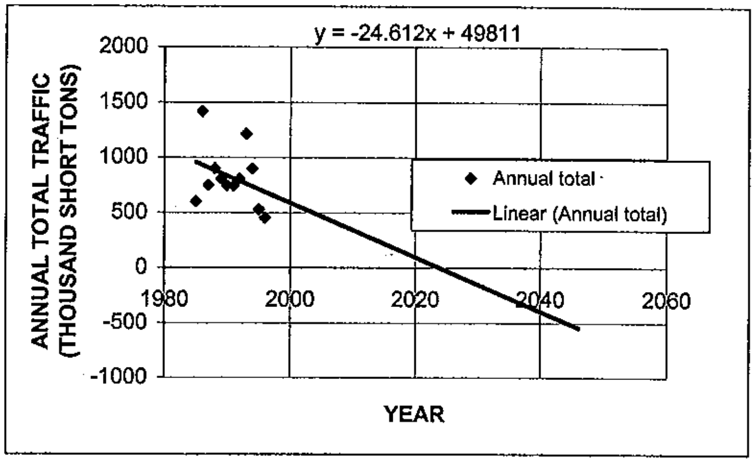
Year	Annual total
1985	409
1986	1320
1987	676
1988	696
1989	680
1990	665
1991	718
1992	753
1993	832
1994	662
1995	430
1996	409



Appendix II
COMPETITIVE STATEMENT OF TRAFFIC AND PREDICTION OF FUTURE TRAFFIC

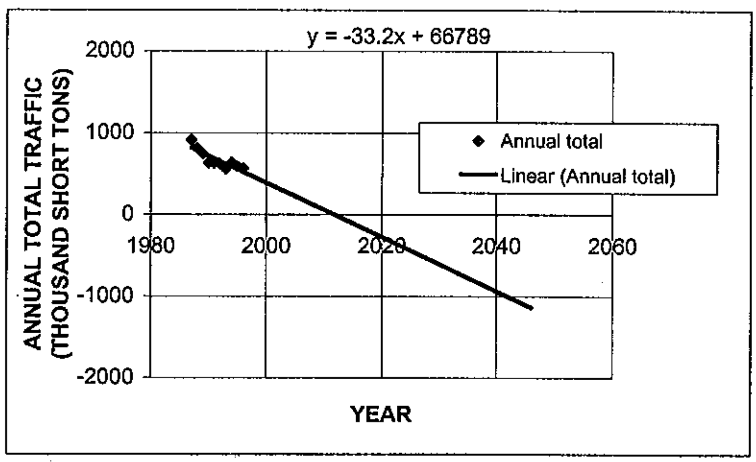
INTRACOASTAL WATERWAY, CALOOSAHATCHEE RIVER TO ANCLOTE RIVER, FL
Past the points: 9, 22, 37, 40, 42, 43

Year	Annual total
1985	602
1986	1417
1987	749
1988	900
1989	803
1990	746
1991	743
1992	805
1993	1,215
1994	897
1995	529
1996	451



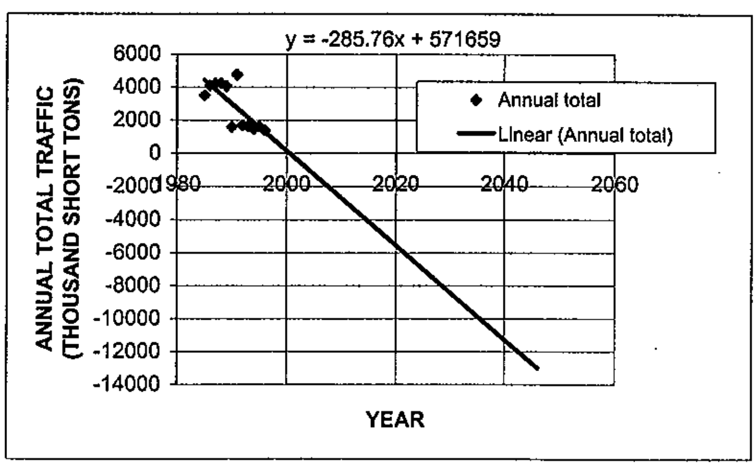
APALACHICOLA, CHATTAHOOCHEE AND FLINT RIVERS, GA AND FL
Past the points: 15, 16

Year	Annual total
1987	912
1988	813
1989	747
1990	636
1991	632
1992	620
1993	559
1994	636
1995	588
1996	567



PENSACOLA HARBOR, FL
Past the points: 25

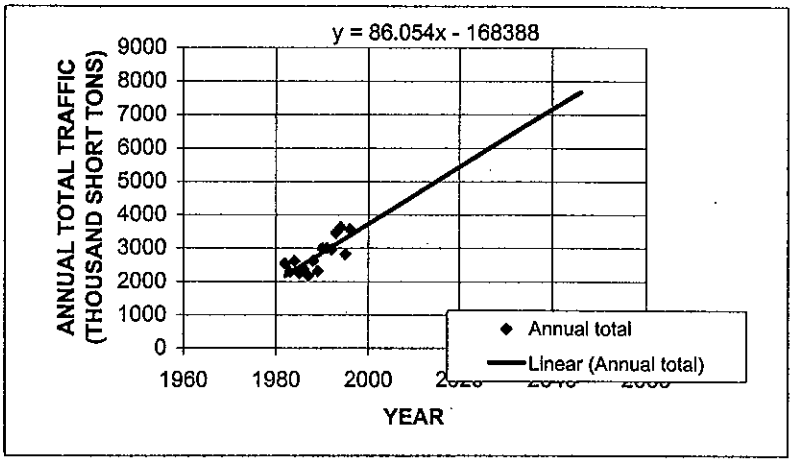
Year	Annual total
1985	3488
1986	4098
1987	4,244
1988	4,227
1989	4,053
1990	1,593
1991	4,760
1992	1,690
1993	1,650
1994	1,466
1995	1,623
1996	1,379



Appendix II
COMPETITIVE STATEMENT OF TRAFFIC AND PREDICTION OF FUTURE TRAFFIC

CANAVERAL HARBOR, FL
Past the points: 4

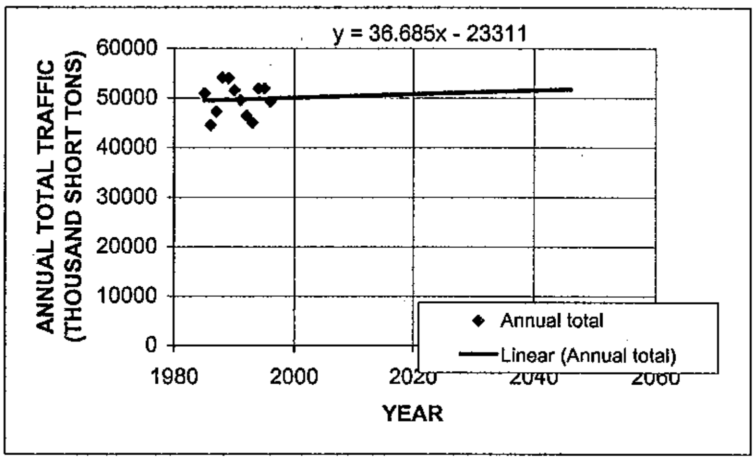
Year	Annual total
1982	2537
1983	2286
1984	2606
1985	2258
1986	2374
1987	2,175
1988	2,612
1989	2,317
1990	2,992
1991	3,004
1992	2,968
1993	3,454
1994	3,625
1995	2,817
1996	3,567



One Year Period Increase Rate
Based on 1 CY2000
0.0231

TAMPA HARBOR, FL
Past the points: 19, 38 and 39

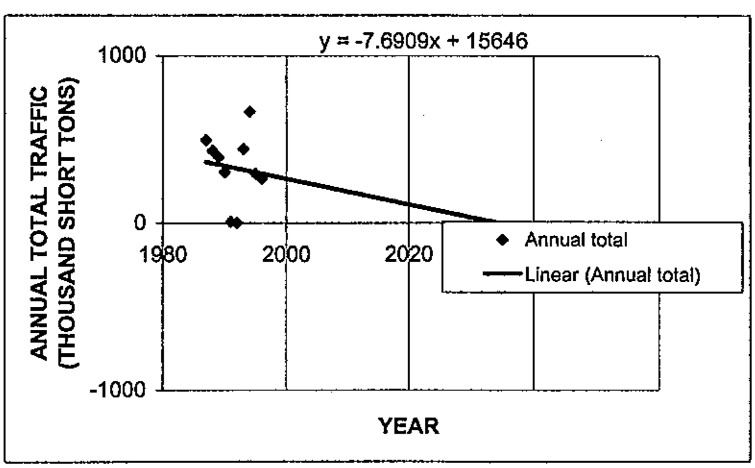
Year	Annual total
1985	50921
1986	44522
1987	47,311
1988	54,071
1989	54,047
1990	51,578
1991	49,548
1992	46,434
1993	44,993
1994	51,905
1995	51,911
1996	49,293



One Year Period Increase Rate
Based on CY2000
0.000733

INTRACOASTAL WATERWAY, MIAMI TO KEY WEST, FL
Past the points: 11

Year	Annual total
1987	495
1988	432
1989	393
1990	305
1991	8
1992	1
1993	441
1994	664
1995	293
1996	267

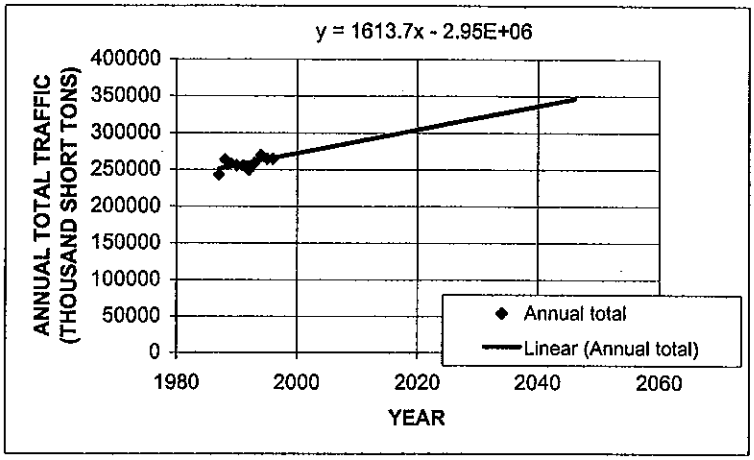


Appendix II
COMPETITIVE STATEMENT OF TRAFFIC AND PREDICTION OF FUTURE TRAFFIC

FLORIDA
All Regions
Past the points: 8, 10, 12, 29

Year	Annual total
1987	242767
1988	263632
1989	258126
1990	255716
1991	255300
1992	249618
1993	258987
1994	269846
1995	264603
1996	264626

One Year Period Increase Rate
Based on CY2000
0.0058



CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 460012
Past the point: 01

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.14	284.13	2.2	130.33	41.76	186.58	617.27	SMALL
2	$6 \geq D > 3$	5.15	147.75	2.2	68.19	51.86	288.48	2574.51	MED
3	$9 \geq D > 6$	8.68	2783.21	2.2	1285.53	45.67	236.97	3136.40	MED
4	$12 \geq D > 9$	10.48	251.30	2.2	116.18	50.89	283.92	4986.84	LARGE
5	Self Propelled	5.95			122.49	31.70	134.06	826.51	301.27
Σ			3466.39		1723.72				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+ n \times 0.0064)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 460012
Past the point: 01

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	2503.10	2.6	971.89	46.60	243.94	760.45	SMALL
2	$6 \geq D > 3$	5.06	92.37	2.6	35.92	48.91	250.61	2196.66	MED
3	$9 \geq D > 6$	7.61	125.21	2.6	48.24	36.78	153.21	1683.02	MED
4	$12 \geq D > 9$	10.41	17.45	2.6	7.18	60.00	270.24	5726.15	LARGE
5	Self Propelled	5.96			97.50	31.71	133.95	825.52	300.01
Σ			2738.12		1160.72				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0064)$.

<u>CY2000 Vessel Group Traffic UPBOUND</u>

Bridge NO: 460019
Past the point: 02

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.14	119.59	1.6	72.19	50.85	224.83	837.72	SMALL
2	$6 \geq D > 3$	5.54	30.17	1.6	18.32	57.25	309.77	3296.88	MED
3	$9 \geq D > 6$	8.70	1368.30	1.6	829.60	51.40	255.25	3736.73	MED
4	$12 \geq D > 9$	10.56	178.85	1.6	108.82	52.08	290.05	5224.57	LARGE
6	Self Propelled	5.25			4.31	27.25	122.25	632.56	256.69
Σ			1696.91		1033.23				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.018)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 460019
Past the point: 02

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.01	1509.44	2.0	719.70	51.41	258.79	873.67	SMALL
2	$6 \geq D > 3$	5.04	48.48	2.0	23.70	58.82	310.47	3178.07	MED
3	$9 \geq D > 6$	8.22	48.48	2.0	22.63	44.48	243.81	3223.12	MED
4	$12 \geq D > 9$	11.42	64.64	2.0	31.25	68.60	254.73	6538.99	LARGE
5	Self Propelled	5.00			2.16	23.00	105.00	391.77	154.56
Σ			1671.05		799.43				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0180)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 700016
Past the point: 03

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.05	21.30	1.	21.30	46.61	176.19	611.57	SMALL
2	$6 \geq D > 3$	4.87	18.82	1.	18.82	64.55	246.30	2659.30	MED
3	$9 \geq D > 6$	7.62	4.62	1.	4.62	42.23	199.38	2081.49	MED
4	$12 \geq D > 9$	11.31	10.30	1.	10.30	46.90	199.79	3441.79	LARGE
5	Free Tugs	7.00			28.05	23.64	68.70	413.10	
6	Self Propelled	6.24			6.04	31.35	138.64	1061.57	522.73
Σ			55.04		89.12				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 700016
Past the point: 03

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	31.60	1.	31.60	47.25	195.10	632.17	SMALL
2	$6 \geq D > 3$	4.87	10.65	1.	10.65	69.80	243.62	2742.72	MED
3	$9 \geq D > 6$	7.33	11.72	1.	11.72	55.63	197.83	2885.72	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	6.95			28.76	23.13	66.76	385.13	
6	Self Propelled	6.14			4.97	36.82	178.71	2495.32	1479.69
Σ			54.33		88.41				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

<u>CY2000 Vessel Group Traffic UPBOUND</u>

Bridge NO: 700030
Past the point: 04

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.50	2.20	1.	2.20	40.00	135.00	440.44	SMALL
2	$6 \geq D > 3$	5.33	1.10	1.	1.10	40.00	173.33	1206.95	MED
3	$9 \geq D > 6$	7.03	53.26	1.	53.26	49.13	274.14	3086.13	MED
4	$12 \geq D > 9$	11.26	6.98	1.	6.98	46.00	198.00	3328.37	LARGE
Σ			63.55		63.55				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times0.0231)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 700030
Past the point: 04

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.38	22.41	1.	22.41	40.98	215.74	679.27	SMALL
2	$6 \geq D > 3$	5.87	97.34	1.	97.34	45.38	250.46	2215.27	MED
3	$9 \geq D > 6$	7.75	174.85	1.	174.85	48.32	268.68	3320.23	MED
4	$12 \geq D > 9$	10.00	5.51	1.	5.51	50.00	279.37	4532.03	LARGE
Σ			299.74		299.74				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0231)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 700184
Past the point: 05

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.05	21.30	1.	21.30	46.61	176.19	611.57	SMALL
2	$6 \geq D > 3$	4.87	18.82	1.	18.82	64.55	246.30	2659.30	MED
3	$9 \geq D > 6$	7.62	4.62	1.	4.62	42.23	199.38	2081.49	MED
4	$12 \geq D > 9$	11.31	10.30	1.	10.30	46.90	199.79	3441.79	LARGE
5	Free Tugs	7.00			28.05	23.52	68.91	411.85	
6	Self Propelled $4 \geq D > 2$	3.67			1.07	19.83	79.97	222.54	139.67
7	Self Propelled $6 \geq D > 4$	5.56			3.20	31.50	135.67	826.33	360.56
8	Self Propelled $10 \geq D > 8$	9.00			1.78	38.00	179.20	1988.44	1037.27
Σ			55.04		89.12				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 700184
Past the point: 05

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	21.60	1.	21.60	46.91	195.09	626.89	SMALL
2	$6 \geq D > 3$	4.87	10.65	1.	10.65	69.80	243.62	2742.72	MED
3	$9 \geq D > 6$	7.33	11.72	1.	11.72	57.39	206.67	3015.04	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	6.95			28.76	23.29	67.04	388.41	
6	Self Propelled $4 \geq D > 2$	3.75			1.42	20.88	84.97	244.77	157.41
7	Self Propelled $6 \geq D > 4$	6.00			1.07	33.67	141.40	968.81	451.02
8	Self Propelled $8 \geq D > 6$	7.00			1.78	38.20	165.12	1433.14	520.18
9	Self Propelled $10 \geq D > 8$	9.00			0.71	70.00	456.15	11941.63	13427.23
Σ			54.33		88.41				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 860034
Past the point: 06

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.13	19.17	1.	19.17	46.37	173.04	621.87	SMALL
2	$6 \geq D > 3$	4.76	18.11	1.	18.11	64.46	237.79	2504.17	MED
3	$9 \geq D > 6$	7.36	3.91	1.	3.91	42.18	205.64	2073.70	MED
4	$12 \geq D > 9$	11.23	11.01	1.	11.01	48.52	216.58	3913.02	LARGE
5	Free Tugs	7.17			9.59	23.04	65.53	409.34	
6	Self Propelled $6 \geq D > 4$	5.42			391.28	28.51	91.50	493.85	172.21
7	Self Propelled $8 \geq D > 6$	7.04			182.50	34.94	142.11	1142.61	448.17
8	Self Propelled $10 \geq D > 8$	9.00			18.46	27.46	137.46	1120.18	436.74
Σ			52.20		657.23				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 860034
Past the point: 06

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.90	25.56	1.	25.56	47.99	198.63	627.06	SMALL
2	$6 \geq D > 3$	4.73	14.56	1.	14.56	60.63	215.42	2196.87	MED
3	$9 \geq D > 6$	7.49	13.85	1.	13.85	56.26	214.36	3082.43	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	7.03			23.79	23.49	68.30	400.54	
6	Self Propelled $6 \geq D > 4$	5.42			390.57	28.52	91.47	494.03	172.24
7	Self Propelled $8 \geq D > 6$	7.04			182.15	34.96	142.13	1143.32	448.26
8	Self Propelled $10 \geq D > 8$	9.00			17.40	27.77	145.76	1452.87	585.15
Σ			54.33		672.14				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 860144
Past the point: 07

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.13	19.17	1.	19.17	46.37	173.04	621.87	SMALL
2	$6 \geq D > 3$	4.76	18.11	1.	18.11	64.46	237.79	2504.17	MED
3	$9 \geq D > 6$	7.36	3.91	1.	3.91	42.18	205.64	2073.70	MED
4	$12 \geq D > 9$	11.23	11.01	1.	11.01	48.52	216.58	3913.02	LARGE
5	Free Tugs	7.17			9.59	23.04	65.53	409.34	
6	Self Propelled $6 \geq D > 4$	5.42			391.28	28.51	91.50	493.85	172.21
7	Self Propelled $8 \geq D > 6$	7.04			182.50	34.94	142.11	1142.61	448.17
8	Self Propelled $10 \geq D > 8$	9.00			18.46	27.46	137.46	1120.18	436.74
Σ			52.20		657.23				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 860144
Past the point: 07

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.90	25.56	1.	25.56	47.99	198.63	627.06	SMALL
2	$6 \geq D > 3$	4.73	14.56	1.	14.56	60.63	215.42	2196.87	MED
3	$9 \geq D > 6$	7.49	13.85	1.	13.85	56.26	214.36	3082.43	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	7.03			23.79	23.49	68.30	400.54	
6	Self Propelled $6 \geq D > 4$	5.42			390.57	28.52	91.47	494.03	172.24
7	Self Propelled $8 \geq D > 6$	7.04			182.15	34.96	142.13	1143.32	448.26
8	Self Propelled $10 \geq D > 8$	9.00			17.40	27.77	145.76	1452.87	585.15
Σ			54.33		672.14				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 860008
Past the point: 08

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.95	25.61	1.	25.61	45.05	166.95	553.28	SMALL
2	$6 \geq D > 3$	5.00	14.34	1.	14.34	43.02	195.33	1511.99	MED
3	$12 \geq D > 9$	10.50	16.39	1.	16.39	59.00	329.00	6998.19	LARGE
4	Free Tugs	6.27			70.68	21.31	56.48	284.19	
5	Self Propelled	7.69			673.03	42.33	283.33	2989.93	3065.81
6	Other Vessels	6.64			90.15	42.33	283.33	2581.68	3069.88
Σ			56.34		890.20				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 860008
Past the point: 08

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.79	44.05	1.	44.05	44.05	197.62	525.70	SMALL
2	$6 \geq D > 3$	4.00	15.37	1.	15.37	15.37	77.00	269.81	MED
3	$9 \geq D > 6$	7.00	11.27	1.	11.27	11.27	150.00	1533.03	MED
4	Free Tugs	6.46			39.95	21.90	58.11	311.44	
5	Self Propelled	7.62			667.91	42.33	283.33	2962.71	3068.22
6	Other Vessels	6.21			84.00	42.33	283.33	2414.50	3069.24
Σ			70.68		862.55				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 010029
Past the point: 09

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.74	23.22	1.	23.22	42.72	195.49	474.70	SMALL
2	$6 \geq D > 3$	4.72	6.15	1.	6.15	42.61	170.14	1229.97	MED
3	Free Tugs	7.29			49.17	23.12	67.29	404.63	
4	Self Propelled $4 \geq D > 2$	3.08			3527.01	13.35	45.24	75.38	29.82
5	Self Propelled $6 \geq D > 4$	5.38			593.13	29.16	97.78	517.79	188.66
6	Self Propelled $10 \geq D > 8$	9.00			1.02	39.33	178.67	2052.60	1064.74
Σ			29.71		4200.04				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 010029
Past the point: 09

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.88	11.27	1.	11.27	43.25	186.71	494.86	SMALL
2	$6 \geq D > 3$	5.00	8.20	1.	8.20	43.12	186.38	1514.30	MED
3	$9 \geq D > 6$	8.00	9.56	1.	9.56	42.94	219.20	2480.21	MED
4	Free Tugs	7.19			48.83	24.26	74.10	439.24	
5	Self Propelled $4 \geq D > 2$	3.08			3529.74	13.35	45.16	75.27	29.77
6	Self Propelled $6 \geq D > 4$	5.38			593.47	29.17	97.85	518.60	189.01
7	Self Propelled $10 \geq D > 8$	9.00			0.34	38.00	180.00	1997.31	1050.66
Σ			28.68		4201.06				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 900047
Past the point: 10

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.40	1.71	1.	1.71	41.00	194.00	331.91	SMALL
2	Free Tugs	6.62			2.73	16.85	44.28	209.34	
3	Self Propelled $4 \geq D > 2$	3.81			292.30	19.00	64.70	152.13	70.81
4	Self Propelled $6 \geq D > 4$	5.00			795.96	19.15	64.30	200.39	72.33
5	Self Propelled $10 \geq D > 8$	9.00			12.98	30.26	89.45	797.40	317.35
6	Self Propelled $12 \geq D > 10$	12.00			49.85	23.00	100.00	895.48	206.08
Σ			1.71		1155.52				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 900047
Past the point: 10

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	3.00	0.34	1.	0.34	45.00	130.00	569.41	SMALL
2	Free Tugs	6.20			3.42	15.25	38.08	139.29	
3	Self Propelled $4 \geq D > 2$	3.81			292.30	19.00	64.70	152.13	70.81
4	Self Propelled $6 \geq D > 4$	5.00			795.96	19.15	64.30	200.39	72.33
5	Self Propelled $10 \geq D > 8$	9.00			12.98	30.26	89.45	797.40	317.35
6	Self Propelled $12 \geq D > 10$	12.00			49.85	23.00	100.00	895.48	206.08
Σ			0.34		1154.50				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 900077
Past the point: 11

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.40	1.71	1.	1.71	41.00	194.00	331.91	SMALL
2	Free Tugs	6.62			2.73	16.85	44.28	209.34	
3	Self Propelled $4 \geq D > 2$	3.81			292.30	19.00	64.70	152.13	70.81
4	Self Propelled $6 \geq D > 4$	5.00			795.96	19.15	64.30	200.39	72.33
5	Self Propelled $10 \geq D > 8$	9.00			12.98	30.26	89.45	797.40	317.35
6	Self Propelled $12 \geq D > 10$	12.00			49.85	23.00	100.00	895.48	206.08
Σ			1.71		1155.52				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 900077
Past the point: 11

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	3.00	0.34	1.	0.34	45.00	130.00	569.41	SMALL
2	Free Tugs	6.20			3.41	15.25	38.08	139.29	
3	Self Propelled $4 \geq D > 2$	3.81			292.30	19.00	64.70	152.13	70.81
4	Self Propelled $6 \geq D > 4$	5.00			795.96	19.15	64.30	200.39	72.33
5	Self Propelled $10 \geq D > 8$	9.00			12.98	30.26	89.45	797.40	317.35
6	Self Propelled $12 \geq D > 10$	12.00			49.85	23.00	100.00	895.48	206.08
Σ			0.34		1154.50				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 900098
Past the point: 12

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.40	1.71	1.	1.71	41.00	194.00	331.91	SMALL
2	Free Tugs	6.62			2.73	16.85	44.28	209.34	
3	Self Propelled $4 \geq D > 2$	3.81			292.30	19.00	64.70	152.13	70.81
4	Self Propelled $6 \geq D > 4$	5.00			795.96	19.15	64.30	200.39	72.33
5	Self Propelled $10 \geq D > 8$	9.00			12.98	30.26	89.45	797.40	317.35
6	Self Propelled $12\geq D >10$	12.00			49.85	23.00	100.00	895.48	206.08
Σ			1.71		1155.52				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+ n \times 0.0058)$.

CY2000 Vessel Groups Traffic DOWNBOUND

Bridge NO: 900098
Past the point: 12

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT TONS**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	3.00	0.34	1.	0.34	45.00	130.00	569.41	SMALL
2	Free Tugs	6.20			3.42	15.25	38.08	139.29	
3	Self Propelled $4 \geq D > 2$	3.81			292.30	19.00	64.70	152.13	70.81
4	Self Propelled $6 \geq D > 4$	5.00			795.96	19.15	64.30	200.39	72.33
5	Self Propelled $10 \geq D > 8$	9.00			12.98	30.26	89.45	797.40	317.35
6	Self Propelled $12 \geq D > 10$	12.00			49.85	23.00	100.00	895.48	206.08
Σ			0.34		1154.50				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 874262
Past the point: 13

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$6 \geq D > 3$	5.20	76.13	1.	76.13	72.00	300.00	3644.22	MED
2	Free tugs	7.46			1080.41	20.33	61.00	310.76	
3	Self Propelled	8.87			1616.70	42.33	283.33	3448.72	3068.20
Σ			76.13		2773.25				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0267)$.

CY2000 Vessel Groups Traffic DOWNBOUND

Bridge NO: 874262
Past the point: 13

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$6 \geq D > 3$	5.12	91.81	1	91.81	72.00	300.00	3585.55	MED
2	Free Tugs	6.88			1065.86	25.58	78.58	451.32	
3	Self Propelled	9.27			1755.53	42.33	283.33	3604.25	3069.20
Σ			91.81		2913.20				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0267)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 874459
Past the point: 14

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.27	28.05	1.	28.05	44.64	187.64	656.70	SMALL
2	$6 \geq D > 3$	4.69	30.89	1.	30.89	54.04	209.41	1842.28	MED
3	$9 \geq D > 6$	7.50	7.10	1.	7.10	43.30	201.90	2130.33	MED
4	$12 \geq D > 9$	11.13	10.65	1.	10.65	48.60	217.20	3905.55	LARGE
5	Free Tugs	6.87			13.49	22.55	63.75	370.13	
6	Self Propelled $4 \geq D > 2$	3.00			392.35	27.52	79.66	214.28	108.12
7	Self Propelled $6 \geq D > 4$	5.00			0.71	23.00	105.00	391.77	154.56
8	Self Propelled $8 \geq D > 6$	7.45			55.04	26.00	132.00	829.03	373.41
9	Self Propelled $10 \geq D > 8$	9.00			13.49	28.00	139.47	1163.66	461.10
Σ			76.69		551.77				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 874459
Past the point: 14

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.62	47.22	1.	47.22	45.17	201.04	503.15	SMALL
2	$6 \geq D > 3$	4.94	17.40	1.	17.40	56.26	206.88	2032.89	MED
3	$9 \geq D > 6$	7.30	14.20	1.	14.20	54.32	206.00	2819.87	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	7.06			14.91	22.81	65.54	398.96	
6	Self Propelled $4 \geq D > 2$	3.00			392.35	27.52	79.66	214.28	108.12
7	Self Propelled $8 \geq D > 6$	7.44			51.84	26.00	132.00	828.27	373.41
8	Self Propelled $10 \geq D > 8$	9.00			12.43	26.30	134.00	1035.21	388.84
Σ			79.89		550.71				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 490003
Past the point: 15

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.19	85.03	1.	85.03	51.02	215.90	835.26	SMALL
2	$6 \geq D > 3$	5.58	24.59	1.	24.59	58.58	316.08	3465.00	MED
3	$9 \geq D > 6$	8.35	116.78	1.	116.78	50.60	246.15	3432.86	MED
4	$12 \geq D > 9$	11.01	92.20	1.	92.20	54.07	318.88	6130.24	LARGE
5	Free Tugs	9.17			53.27	25.48	74.47	575.55	
6	Self Propelled	5.25			4.10	27.25	122.25	632.56	256.69
Σ			318.59		375.96				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 490003
Past the point: 15

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.05	252.00	1.9	135.22	50.86	266.81	921.18	SMALL
2	$6 \geq D > 3$	4.90	39.95	1.9	21.51	62.48	327.98	3460.86	MED
3	$9 \geq D > 6$	8.22	36.88	1.9	19.46	45.27	250.51	3412.00	MED
4	$12 \geq D > 9$	11.71	50.20	1.9	27.66	72.49	256.24	7074.56	LARGE
5	Self Propelled	5.00			2.05	23.00	105.00	391.77	154.56
Σ			379.03		205.90				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 500086
Past the point: 16

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	9.22	2.7	3.07	50.90	281.29	940.33	SMALL
2	$6 \geq D > 3$	5.33	3.07	2.7	1.02	47.67	263.37	2180.53	MED
3	$9 \geq D > 6$	8.14	135.22	2.7	51.22	47.04	239.00	3074.95	MED
4	$12 \geq D > 9$	10.00	3.07	2.7	1.02	41.33	229.20	3214.26	LARGE
Σ			154.26		56.34				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+ n \times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 500086
Past the point: 16

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.99	128.05	1.5	86.05	47.02	241.62	749.73	SMALL
2	$6 \geq D > 3$	6.00	5.12	1.5	3.07	35.00	196.00	1335.44	MED
3	$9 \geq D > 6$	7.00	2.05	1.5	2.05	35.00	197.50	1569.93	MED
Σ			135.22		91.17				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

<u>CY2000 Vessel Group Traffic UPBOUND</u>

Bridge NO: 510951
Past the point: 17

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	1059.08	2.1	499.91	52.14	259.06	879.10	SMALL
Σ			1059.08		499.91				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.018)$.

CY2000 Vessel Groups Traffic DOWNBOUND

Bridge NO: 510951
Past the point: 17

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	9.70	2.2	4.31	53.77	289.17	1009.51	SMALL
2	$6 \geq D > 3$	5.00	1.077	2.2	1.077	54.10	297.50	2610.97	MED
3	$9 \geq D > 6$	8.81	1081.71	2.2	500.99	52.13	258.80	3868.12	MED
4	$12 \geq D > 9$	10.00	3.23	2.2	1.077	47.67	249.17	3954.50	LARGE
Σ			1095.72		507.46				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.018)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 510048
Past the point: 18

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.15	106.66	1.6	67.88	51.02	223.68	842.44	SMALL
2	$6 \geq D > 3$	5.54	30.17	1.6	19.39	57.25	309.77	3296.88	MED
3	$9 \geq D > 6$	8.70	1347.83	1.6	855.46	51.44	255.47	3742.56	MED
4	$12 \geq D > 9$	10.94	104.51	1.6	65.72	53.28	312.67	5932.40	LARGE
5	Self Propelled	5.25			4.31	27.25	122.25	632.56	256.69
Σ			1589.17		1008.45				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.018)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 510048
Past the point: 18

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.01	1441.56	2.0	732.63	51.51	259.15	876.88	SMALL
2	$6 \geq D > 3$	5.04	48.48	2.0	24.78	58.82	310.47	3178.07	MED
3	$9 \geq D > 6$	8.17	44.17	2.0	22.63	44.02	243.86	3207.51	MED
4	$12 \geq D > 9$	11.71	52.79	2.0	26.94	72.49	256.24	7074.56	LARGE
6	Self Propelled	5.00			2.16	23.00	105.00	391.77	154.56
Σ			1587.01		809.13				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.018)$.

CY2000 Vessel Groups Traffic UPBOUND

Bridge NO: 100100
Past the point: 19

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.04	194.57	1.1	171.50	36.41	187.78	450.14	SMALL
2	$6 \geq D > 3$	5.18	128.38	1.1	112.33	69.17	445.97	5565.69	MED
3	$9 \geq D > 6$	8.11	385.13	1.1	336.99	53.57	301.92	4562.80	MED
4	$12 \geq D > 9$	10.79	79.23	1.1	71.21	64.10	269.86	6078.16	LARGE
5	$D > 12$	25.78	1009.96	1.1	881.58	79.66	482.31	33399.79	LARGE
6	Self Propelled Domestic	11.15			1548.54	44.17	230.36	13497.87	5797.69
7	Self Propelled Foreign	22.37			1287.77	42.33	283.33	8697.63	3068.13
Σ			1797.27		4409.93				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.00073)$.

CY2000 Vessel Groups Traffic DOWNBOUND

Bridge NO: 100100
Past the point: 19

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.02	258.76	1.2	216.64	44.35	212.65	684.06	SMALL
2	$6 \geq D > 3$	5.14	569.67	1.2	472.39	72.62	427.99	5583.95	MED
3	$9 \geq D > 6$	8.26	329.97	1.2	276.81	51.55	296.21	4483.99	MED
4	$12 \geq D > 9$	10.81	51.15	1.2	43.13	80.84	416.46	11955.43	LARGE
5	$D > 12$	25.95	574.69	1.2	487.43	81.11	503.78	34596.68	LARGE
6	Self Propelled Domestic	8.92			1532.49	43.81	227.31	9683.13	5114.219
7	Self Propelled Foreign	24.78			1303.82	42.33	283.33	9634.65	3067.52
Σ			1784.23		4332.70				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.000733)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 110063
Past the point: 20

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPALCEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	14.06	1.	14.06	48.93	269.59	866.01	SMALL
2	$6 \geq D > 3$	5.97	180.12	1.	180.12	49.95	278.35	2699.02	MED
3	$9 \geq D > 6$	7.55	110.96	1.	110.96	50.02	283.92	3486.29	MED
4	$12 \geq D > 9$	11.50	0.76	1.	0.76	50.00	282.75	5280.83	LARGE
5	Free Tugs	7.61			8.36	23.54	62.42	364.99	
6	Self Propelled $4 \geq D > 2$	4.00			85.88	40.53	100.88	539.43	244.12
7	Self Propelled $6 \geq D > 4$	5.00			315.78	40.00	96.20	624.24	221.65
8	Self Propelled $8 \geq D > 6$	7.00			2.28	24.00	64.80	353.21	129.39
9	Other Vessels	8.00			79.04	35.90	96.50	899.21	354.76
Σ			305.90		796.86				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.031)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 110063
Past the point: 20

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.01	307.80	1.	307.80	49.89	279.05	906.22	SMALL
2	$6 \geq D > 3$	5.00	0.76	1.	0.76	47.60	226.30	1686.06	MED
3	$9 \geq D > 6$	7.00	0.38	1.	0.38	30.00	120.00	817.61	MED
4	Free Tugs	7.63			4.94	23.53	62.47	365.92	
5	Self Propelled $4 \geq D > 2$	4.00			86.26	40.53	100.86	539.25	244.02
6	Self Propelled $6 \geq D > 4$	5.00			315.40	40.00	96.20	624.24	221.65
7	Self Propelled $8 \geq D > 6$	7.00			2.28	24.00	64.80	353.21	129.39
8	Other Vessels	8.00			79.04	35.90	96.50	899.21	354.76
Σ			308.94		796.86				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times0.031)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 124044
Past the point: 21

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.14	105.51	1.2	30.05	50.26	212.45	786.92	SMALL
2	$6 \geq D > 3$	5.95	610.54	1.2	173.81	45.37	226.81	2007.73	MED
3	$9 \geq D > 6$	7.78	232.54	1.2	66.24	46.72	232.12	2817.54	MED
4	$12 \geq D > 9$	11.01	92.20	1.2	26.29	54.07	318.88	6130.24	LARGE
5	Self Propelled $4 \geq D > 2$	3.00			0.34	11.50	39.90	44.66	20.55
6	Self Propelled $6 \geq D > 4$	5.17			2.05	29.60	131.27	699.96	301.09
7	Self Propelled $10 \geq D > 8$	9.00			0.34	38.00	180.00	1997.31	1050.66
Σ			346.93		299.13				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 124044
Past the point: 21

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.32	319.61	1.5	208.64	46.13	233.20	488.92	SMALL
2	$6 \geq D > 3$	4.87	17.76	1.5	11.61	58.20	290.57	2924.10	MEDIUM
3	$9 \geq D > 6$	8.22	12.29	1.5	7.85	45.27	250.51	3412.00	MEDIUM
4	$12 \geq D > 9$	11.71	16.73	1.5	10.93	72.49	256.24	7074.56	LARGE
5	Self Propelled $4 \geq D > 2$	3.00			0.34	11.50	39.90	44.66	20.55
6	Self Propelled $6 \geq D > 4$	5.00			1.02	25.53	117.53	497.14	207.90
7	Self Propelled $10 \geq D > 8$	9.00			1.02	39.33	178.67	2052.60	1064.74
Σ			366.74		241.76				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 130054
Past the point: 22

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.73	23.90	1.	23.90	42.80	192.76	467.64	SMALL
2	$6 \geq D > 3$	4.72	6.15	1.	6.15	42.61	170.14	1229.97	MED
3	Free Tugs	7.25			47.81	23.08	67.27	401.34	
4	Self Propelled $4 \geq D > 2$	3.03			3359.35	12.42	41.00	54.28	21.53
5	Self Propelled $6 \geq D > 4$	5.39			633.76	31.48	111.86	618.36	231.18
6	Self Propelled $8 \geq D > 6$	7.00			583.23	35.00	150.00	1192.35	416.65
7	Self Propelled $10 \geq D > 8$	9.00			1.02	39.33	178.67	2052.60	1064.74
Σ			29.71		4655.22				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 130054
Past the point: 22

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.86	11.95	1.	11.95	43.37	181.76	479.59	SMALL
2	$6 \geq D > 3$	5.00	8.20	1.	8.20	43.12	186.38	1514.30	MED
3	$9 \geq D > 6$	8.00	9.56	1.	9.56	42.94	219.20	2480.21	MED
4	Free Tugs	7.19			49.51	24.29	73.52	436.74	
5	Self Propelled $4 \geq D > 2$	3.03			3362.08	12.42	40.91	54.18	21.49
6	Self Propelled $6 \geq D > 4$	5.40			613.62	31.38	110.65	611.29	226.41
7	Self Propelled $8 \geq D > 6$	7.00			583.23	35.00	150.00	1192.35	416.65
8	Self Propelled $10 \geq D > 8$	9.00			0.34	38.00	180.00	1997.31	1050.66
Σ			29.71		4638.48				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+ n \times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 720022
Past the point: 23

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.97	69.12	1.	69.12	46.16	252.35	783.41	SMALL
2	$6 \geq D > 3$	5.97	213.84	1.	213.84	46.24	257.77	2362.92	MED
3	$9 \geq D > 6$	7.99	166.32	1.	166.32	41.23	230.99	2525.85	MED
4	$12 \geq D > 9$	10.00	31.32	1.	31.32	35.95	194.36	2268.69	LARGE
5	$D > 12$	21.92	49.68	1.	49.68	80.11	424.46	24218.40	LARGE
6	Free Tugs	7.77			93.96	22.93	64.02	397.96	
7	Self Propelled	20.53			1877.04	39.42	239.08	6528.86	2148.70
Σ			530.28		2501.28				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+ n \times 0.0184)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 720022
Past the point: 23

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT TONS**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.98	399.60	1.	399.60	44.17	245.46	722.06	SMALL
2	$6 \geq D > 3$	5.31	24.84	1.	24.84	67.70	344.82	4482.94	MED
3	$9 \geq D > 6$	8.92	29.16	1.	29.16	35.00	195.00	1975.22	MED
4	$12 \geq D > 9$	10.60	28.08	1.	28.08	50.00	270.00	5764.18	LARGE
5	$D > 12$	16.08	36.72	1.	36.72	80.67	428.50	18081.53	LARGE
6	Free Tugs	7.82			113.4	23.10	64.95	422.94	
7	Self Propelled	20.21			1820.88	39.37	238.13	6146.91	1940.10
Σ			518.40		2452.68				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0184)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 720061
Past the point: 24

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.30	75.60	1.	75.60	43.82	229.25	805.64	SMALL
2	$6 \geq D > 3$	5.51	171.72	1.	171.72	48.27	257.27	2268.85	MED
3	$9 \geq D > 6$	8.21	102.60	1.	102.60	35.84	159.34	1535.80	MED
4	$12 \geq D > 9$	10.16	48.60	1.	48.60	40.03	209.71	3011.67	LARGE
5	Free Tugs	7.89			147.96	22.72	65.08	409.51	
6	Self Propelled	6.29			7.56	33.86	156.31	1192.55	550.69
Σ			398.52		406.08				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0184)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 720061
Past the point: 24

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.02	304.56	1.	304.56	42.07	212.56	615.53	SMALL
2	$6 \geq D > 3$	5.27	11.88	1.	11.88	57.15	260.91	2800.07	MED
3	$9 \geq D > 6$	8.89	20.52	1.	20.52	35.00	195.00	1969.63	MED
4	$12 \geq D > 9$	10.23	14.04	1.	14.04	46.65	253.28	4629.95	LARGE
5	$D > 12$	14.80	5.40	1.	5.40	66.00	411.72	12910.67	LARGE
6	Free Tugs	7.80			118.80	22.44	63.14	373.35	
7	Self Propelled	6.43			7.56	33.43	165.74	1330.22	614.61
Σ			356.40		482.76				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0184)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 480035
Past the point: 25

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.06	348.30	2.3	153.66	41.33	225.96	644.32	SMALL
2	$6 \geq D > 3$	5.47	52.24	2.3	23.56	47.42	246.71	2114.83	MED
3	$9 \geq D > 6$	8.32	284.78	2.3	126.00	44.62	233.10	2947.52	MED
4	$12 \geq D > 9$	10.44	62.49	2.3	27.66	49.85	265.05	4520.48	LARGE
5	$D > 12$	17.00	5.12	2.3	2.05	66.00	361.00	13141.59	LARGE
6	Self Propelled	17.29			56.34	42.33	283.33	6722.48	3067.55
Σ			752.93		389.27				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0058)$.

<u>CY2000 Vessel Group Traffic DOWNBOUND</u>

Bridge NO: 480035
Past the point: 25

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.99	523.47	2.2	238.69	44.58	232.44	697.29	SMALL
2	$6 \geq D > 3$	5.00	7.17	2.2	3.07	45.86	253.57	1878.08	MED
3	$9 \geq D > 6$	8.25	194.64	2.2	89.12	41.05	226.08	2573.90	MED
4	$12 \geq D > 9$	10.00	5.12	2.2	3.07	35.00	195.00	2214.37	LARGE
5	$D > 12$	23.00	5.12	2.2	3.07	66.00	361.00	17779.79	LARGE
6	Self Propelled	19.93			59.42	42.33	283.33	7748.94	3057.17
Σ			735.52		396.44				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 480118
Past the point: 26

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.13	438.86	2.5	175.55	40.27	206.24	618.20	SMALL
2	$6 \geq D > 3$	5.28	281.48	2.5	113.00	45.61	252.41	2063.25	MED
3	$9 \geq D > 6$	8.65	3910.42	2.5	1562.76	42.95	228.54	2837.70	MED
4	$12 \geq D > 9$	10.36	379.34	2.5	151.33	49.89	274.08	4665.90	LARGE
5	Self Propelled	5.25			4.04	27.25	122.25	632.56	256.69
Σ			5010.10		2006.66				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0022)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 480118
Past the point: 26

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	4389.64	2.8	1555.70	43.66	233.22	684.03	SMALL
2	$6 \geq D > 3$	4.64	150.32	2.8	53.47	46.07	260.06	1918.98	MED
3	$9 \geq D > 6$	8.01	288.54	2.8	100.89	39.96	198.39	2287.30	MED
4	$12 \geq D > 9$	10.70	10.09	2.8	4.04	66.60	274.60	6702.27	LARGE
5	Self Propelled	5.00			2.02	23.00	105.00	391.77	154.56
Σ			4838.59		1716.10				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0022)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 480139
Past the point: 27

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.11	135.47	2.2	151.89	39.24	189.23	559.00	SMALL
2	$6 \geq D > 3$	5.21	218.60	2.2	97.50	44.96	252.06	2013.04	MED
3	$9 \geq D > 6$	8.62	2607.78	2.2	1163.80	45.06	235.62	3057.25	MED
4	$12 \geq D > 9$	10.35	299.67	2.2	133.42	50.09	275.21	4702.37	LARGE
5	Self Propelled	5.25			4.11	27.25	122.25	632.56	256.69
Σ			3466.77		1550.71				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0064)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 480139
Past the point: 27

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	3096.29	2.7	1167.90	45.48	240.51	733.32	SMALL
2	$6 \geq D > 3$	5.06	92.37	2.7	33.87	48.91	250.61	2196.66	MED
3	$9 \geq D > 6$	7.64	129.31	2.7	49.26	37.18	156.07	1736.99	MED
4	$12 \geq D > 9$	10.70	10.26	2.7	4.11	66.60	274.60	6702.27	LARGE
5	Self Propelled	5.00			2.05	23.00	105.00	391.77	154.56
Σ			3328.23		1257.20				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0064)$.

<u>CY2000 Vessel Group Traffic UPBOUND</u>

Bridge NO: 734071
Past the point: 28

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.05	36.93	1.	36.93	47.31	220.28	745.19	SMALL
2	$6 \geq D > 3$	4.87	19.17	1.	19.17	64.19	244.89	2632.50	MED
3	$9 \geq D > 6$	8.00	1.42	1.	1.42	41.25	187.50	2016.05	MED
4	$12 \geq D > 9$	11.40	3.55	1.	3.55	48.60	203.20	3657.30	LARGE
5	Free Tugs	7.18			22.01	23.53	67.25	409.63	
6	Self Propelled $4 \geq D > 2$	3.67			1.07	19.83	79.97	222.54	139.67
7	Self Propelled $6 \geq D > 4$	5.63			2.84	32.56	139.50	880.65	388.36
8	Self Propelled $10 \geq D > 8$	9.00			1.78	38.00	179.20	1988.44	1037.27
Σ			61.07		88.77				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0153)$.

CY2000 Vessel Groups Traffic DOWNBOUND

Bridge NO: 734071
Past the point: 28

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.19	26.63	1.	26.63	48.80	221.86	792.38	SMALL
2	$6 \geq D > 3$	5.00	13.14	1.	13.14	63.89	225.37	2420.04	MED
3	$9 \geq D > 6$	7.30	13.14	1.	13.14	54.67	199.65	2792.31	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	7.04			27.70	23.08	66.21	381.04	
6	Self Propelled $4 \geq D > 2$	3.75			1.42	20.88	84.97	244.77	157.72
7	Self Propelled $6 \geq D > 4$	6.00			1.07	33.67	141.40	968.81	450.17
8	Self Propelled $8 \geq D > 6$	7.00			1.78	38.20	165.12	1433.14	520.18
9	Self Propelled $10 \geq D > 8$	9.00			0.71	70.00	456.15	11941.63	13427.22
Σ			53.26		86.28				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 740055
Past the point: 29

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.34	69.66	1.	69.66	44.01	232.03	824.40	SMALL
2	$6 \geq D > 3$	5.51	162.88	1.	162.88	48.43	258.14	2276.64	MED
3	$9 \geq D > 6$	8.21	97.32	1.	97.32	35.84	159.34	1535.80	MED
4	$12 \geq D > 9$	10.16	46.10	1.	46.10	40.03	209.71	3011.67	LARGE
5	Free Tugs	7.90			140.34	22.98	66.67	418.56	
6	Self Propelled	6.29			7.17	33.86	156.31	1192.55	550.69
Σ			375.96		523.47				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 740055
Past the point: 29

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.03	286.83	1.	286.83	42.16	213.27	619.92	SMALL
2	$6 \geq D > 3$	5.27	11.27	1.	11.27	57.15	260.91	2800.07	MED
3	$9 \geq D > 6$	8.89	19.46	1.	19.46	35.00	195.00	1969.63	MED
4	$12 \geq D > 9$	10.23	13.32	1.	13.32	46.65	253.28	4629.95	LARGE
5	$D > 12$	14.80	5.12	1.	5.12	66.00	411.72	12910.67	LARGE
6	Free Tugs	7.91			112.68	22.71	63.98	416.90	
7	Self Propelled	6.43			7.17	33.43	165.74	1330.22	614.61
Σ			336.00		455.86				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 740088
Past the point: 30

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.34	72.23	1.	72.23	44.14	232.58	830.10	SMALL
2	$6 \geq D > 3$	5.48	181.10	1.	181.10	49.69	260.38	2342.40	MED
3	$9 \geq D > 6$	8.33	54.98	1.	54.98	36.53	196.27	1940.08	MED
4	$12 \geq D > 9$	10.16	52.82	1.	52.82	40.03	209.71	3011.67	LARGE
5	Free Tugs	7.93			132.59	23.19	67.14	430.82	
6	Self Propelled	22.48			284.59	42.33	283.33	8740.39	3103.50
Σ			361.13		778.32				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times0.0181)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 740088
Past the point: 30

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.02	253.33	1.	253.33	43.51	231.45	684.68	SMALL
2	$6 \geq D > 3$	5.15	21.56	1.	21.56	63.83	278.50	3116.87	MED
3	$9 \geq D > 6$	8.89	22.64	1.	22.64	35.00	195.00	1969.63	MED
4	$12 \geq D > 9$	10.23	16.17	1.	16.17	46.65	253.28	4629.95	LARGE
5	$D > 12$	14.80	7.55	1.	7.55	66.00	411.72	12910.67	LARGE
6	Free Tugs	7.93			106.72	23.12	65.26	425.14	
7	Self Propelled	22.48			284.60	42.33	283.33	8740.39	3448.33
Σ			321.24		712.56				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0181)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 570091
Past the point: 31

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.14	230.91	2.0	110.84	41.76	186.58	617.27	SMALL
2	$6 \geq D > 3$	5.15	120.08	2.0	57.47	51.86	288.48	2574.51	MED
3	$9 \geq D > 6$	8.67	2306.05	2.0	1108.38	45.52	236.43	3117.12	MED
4	$12 \geq D > 9$	10.38	254.52	2.0	122.13	50.73	280.08	4852.77	LARGE
5	Self Propelled	5.00			5.13	26.20	116.80	560.29	239.62
Σ			2911.56		1403.95				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0064)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 570091
Past the point: 31

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	2602.65	2.5	1035.52	46.57	243.99	759.29	SMALL
2	$6 \geq D > 3$	5.06	92.37	2.5	36.95	48.91	250.61	2196.66	MED
3	$9 \geq D > 6$	7.61	125.21	2.5	49.26	36.78	153.21	1683.02	MED
4	$12 \geq D > 9$	10.41	17.45	2.5	7.18	60.00	270.24	5726.15	LARGE
5	Self Propelled	4.67			3.08	22.67	101.67	351.60	153.57
Σ			2837.66		1131.99				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0064)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 050044
Past the point: 32

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.95	13.32	1.	13.32	44.53	189.12	536.18	SMALL
2	$6 \geq D > 3$	4.86	7.17	1.	7.17	43.32	179.18	1464.06	MED
3	$9 \geq D > 6$	8.08	4.10	1.	4.10	47.12	227.92	2893.79	MED
4	Free Tugs	7.45			45.76	24.90	75.96	484.64	
5	Self Propelled	3.14			43.03	15.70	51.31	115.05	46.26
Σ			8.20		37.90				

For future trip projections, annual trips of n years later in excess of 2000 multiply by ($1+n \times 0.0058$).

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 050044
Past the point: 32

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.15	16.05	1.	16.05	43.30	183.04	557.99	SMALL
2	$6 \geq D > 3$	4.58	4.10	1.	4.10	44.78	170.50	1158.48	MED
3	$9 \geq D > 6$	7.00	0.68	1.	0.68	35.00	187.50	1490.44	MED
4	$12 \geq D > 9$	10.00	0.68	1.	0.68	72.00	460.00	10745.78	LARGE
5	Free Tugs	7.55			38.24	23.82	69.80	450.50	
6	Self Propelled $4 \geq D > 2$	3.00			41.32	14.97	46.94	68.42	27.03
7	Self Propelled $6 \geq D > 4$	5.00			1.02	25.53	117.53	497.14	207.90
8	Self Propelled $10 \geq D > 8$	9.00			1.02	39.33	178.67	2052.60	1064.74
Σ			21.51		103.46				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 930157
Past the point: 33

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.12	21.30	1.	21.30	46.25	165.76	588.72	SMALL
2	$6 \geq D > 3$	4.75	18.46	1.	18.46	64.26	239.77	2501.97	MED
3	$9 \geq D > 6$	7.38	4.62	1.	4.62	45.31	203.23	2264.30	MED
4	$12 \geq D > 9$	11.23	11.01	1.	11.01	48.52	216.58	3913.02	LARGE
5	Free Tugs	7.16			19.53	22.07	62.48	379.32	
6	Self propelled $4 \geq D > 2$	3.40			1.78	16.50	63.94	151.39	86.07
7	Self propelled $6 \geq D > 4$	5.40			3.55	31.11	138.36	810.64	344.69
8	Self propelled $8 \geq D > 6$	7.00			0.71	26.00	132.00	779.46	373.41
9	Self propelled $10 \geq D > 8$	9.00			2.13	38.67	179.33	2024.96	1057.80
Σ			55.39		83.09				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 930157
Past the point: 33

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.92	26.99	1.	26.99	48.15	193.07	613.31	SMALL
2	$6 \geq D > 3$	4.73	14.56	1.	14.56	60.63	215.42	2196.87	MED
3	$9 \geq D > 6$	7.47	14.91	1.	14.91	56.78	212.13	3091.41	MED
4	Free Tugs	7.00			31.60	22.92	66.53	383.48	
5	Self Propelled $4 \geq D > 2$	3.57			2.49	18.64	74.24	197.12	119.76
6	Self Propelled $6 \geq D > 4$	5.50			1.42	35.90	159.45	1036.44	472.09
7	Self Propelled $8 \geq D > 6$	7.00			2.49	34.71	155.66	1246.37	493.73
8	Self Propelled $10 \geq D > 8$	9.00			0.71	69.30	469.15	12044.59	13384.59
Σ			56.46		95.16				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 930004
Past the point: 34

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.12	21.30	1.	21.30	46.25	165.76	588.72	SMALL
2	$6 \geq D > 3$	4.75	18.46	1.	18.46	64.26	239.77	2501.97	MED
3	$9 \geq D > 6$	7.38	4.62	1.	4.62	45.31	203.23	2264.30	MED
4	$12 \geq D > 9$	11.23	11.01	1.	11.01	48.52	216.58	3913.02	LARGE
5	Free Tugs	7.16			19.53	22.07	62.48	379.32	
6	Self propelled $4 \geq D > 2$	3.40			1.78	16.50	63.94	151.39	86.07
7	Self propelled $6 \geq D > 4$	5.40			3.55	31.11	138.36	810.64	344.69
8	Self propelled $8 \geq D > 6$	7.00			0.71	26.00	132.00	779.46	373.41
9	Self propelled $10 \geq D > 8$	9.00			2.13	38.67	179.33	2024.96	1057.80
Σ			55.39		83.08				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 930004
Past the point: 34

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.92	26.99	1.	26.99	48.15	193.07	613.31	SMALL
2	$6 \geq D > 3$	4.73	14.56	1.	14.56	60.63	215.42	2196.87	MED
3	$9 \geq D > 6$	7.47	14.91	1.	14.91	56.78	212.13	3091.41	MED
4	Free Tugs	7.00			31.60	22.92	66.53	383.48	
5	Self Propelled $4 \geq D > 2$	3.57			2.49	18.64	74.24	197.12	119.76
6	Self Propelled $6 \geq D > 4$	5.50			1.42	35.90	159.45	1036.44	472.09
7	Self Propelled $8 \geq D > 6$	7.00			2.49	34.71	155.66	1246.37	493.73
8	Self Propelled $10 \geq D > 8$	9.00			0.71	69.30	469.15	12044.59	13384.59
Σ			56.46		95.16				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 930005
Past the point: 35

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.12	21.30	1.	21.30	46.25	165.76	588.72	SMALL
2	$6 \geq D > 3$	4.75	18.46	1.	18.46	64.26	239.77	2501.97	MED
3	$9 \geq D > 6$	7.38	4.62	1.	4.62	45.31	203.23	2264.30	MED
4	$12 \geq D > 9$	11.23	11.01	1.	11.01	48.52	216.58	3913.02	LARGE
5	Free Tugs	7.16			19.53	22.07	62.48	379.32	
6	Self propelled $4 \geq D > 2$	3.40			1.78	16.50	63.94	151.39	86.07
7	Self propelled $6 \geq D > 4$	5.40			3.55	31.11	138.36	810.64	344.69
8	Self propelled $8 \geq D > 6$	7.00			0.71	26.00	132.00	779.46	373.41
9	Self propelled $10 \geq D > 8$	9.00			2.13	38.67	179.33	2024.96	1057.80
Σ			55.39		83.08				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 930005
Past the point: 35

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.92	26.99	1.	26.99	48.15	193.07	613.31	SMALL
2	$6 \geq D > 3$	4.73	14.56	1.	14.56	60.63	215.42	2196.87	MED
3	$9 \geq D > 6$	7.47	14.91	1.	14.91	56.78	212.13	3091.41	MED
4	Free Tugs	7.00			31.60	22.92	66.53	383.48	
5	Self Propelled $4 \geq D > 2$	3.57			2.49	18.64	74.24	197.12	119.76
6	Self Propelled $6 \geq D > 4$	5.50			1.42	35.90	159.45	1036.44	472.09
7	Self Propelled $8 \geq D > 6$	7.00			2.49	34.71	155.66	1246.37	493.73
8	Self Propelled $10 \geq D > 8$	9.00			0.71	69.30	469.15	12044.59	13384.59
Σ			56.46		95.16				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 930060
Past the point: 36

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.13	18.82	1.	18.82	46.87	175.39	632.43	SMALL
2	$6 \geq D > 3$	4.76	18.11	1.	18.11	64.46	237.79	2504.17	MED
3	$9 \geq D > 6$	7.36	3.91	1.	3.91	42.18	205.64	2073.70	MED
4	$12 \geq D > 9$	11.23	11.01	1.	11.01	48.52	216.58	3913.02	LARGE
5	Free Tugs	7.19			9.23	23.17	65.92	414.04	
6	Self Propelled $4 \geq D > 2$	3.00			1.07	11.50	39.90	44.66	20.55
7	Self Propelled $6 \geq D > 4$	5.00			0.71	23.00	105.00	391.77	154.56
8	Self Propelled $8 \geq D > 6$	7.10			6.75	34.17	207.67	1762.80	695.47
9	Self Propelled $10 \geq D > 8$	9.00			3.20	34.44	163.56	1684.03	795.63
Σ			51.84		72.79				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 930060
Past the point: 36

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.90	25.21	1.	25.21	48.50	200.18	633.92	SMALL
2	$6 \geq D > 3$	4.73	14.56	1.	14.56	60.63	215.42	2196.87	MED
3	$9 \geq D > 6$	7.49	13.85	1.	13.85	57.08	214.49	3139.23	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	7.05			23.43	23.45	68.09	400.35	
6	Self Propelled $4 \geq D > 2$	3.00			1.07	11.50	39.90	44.66	20.55
7	Self Propelled $8 \geq D > 6$	7.25			2.84	26.00	132.00	807.30	373.41
8	Self Propelled $10 \geq D > 8$	9.00			2.13	40.43	244.38	4682.97	2897.93
Σ			54.33		87.35				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 150049
Past the point: 37

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT *D* (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.54	52.93	1.3	40.63	54.60	207.66	1069.11	SMALL
2	$6 \geq D > 3$	4.94	21.51	1.3	16.73	58.04	293.93	3018.56	MED
3	$9 \geq D > 6$	8.05	34.15	1.3	26.29	36.08	193.07	1848.43	MED
4	Self Propelled $4 \geq D > 2$	3.02			3305.74	12.37	40.92	53.71	21.25
5	Self Propelled $6 \geq D > 4$	5.00			289.91	31.98	106.04	550.08	195.44
6	Self Propelled $8 \geq D > 6$	7.34			62.83	35.00	150.00	1249.75	448.35
7	Self Propelled $10 \geq D > 8$	9.00			1.02	39.33	178.67	2052.60	1064.74
Σ			108.59		3743.16				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 150049
Past the point: 37

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.06	47.46	1.1	45.07	36.26	170.05	424.26	SMALL
2	$6 \geq D > 3$	4.94	11.95	1.1	11.27	41.41	185.70	1381.34	MED
3	$9 \geq D > 6$	8.30	38.59	1.1	3.88	46.60	217.72	2883.11	MED
6	Self Propelled $4 \geq D > 2$	3.02			3308.47	12.37	40.83	53.60	21.21
7	Self Propelled $6 \geq D > 4$	5.00			290.01	32.00	106.18	551.70	196.14
8	Self Propelled $8 \geq D > 6$	7.34			62.83	35.00	150.00	1249.75	448.35
9	Self Propelled $10 \geq D > 8$	9.00			0.34	38.00	180.00	1997.31	1050.66
Σ			98.00		3755.11				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+ n \times 0.0058)$.

CY2000 Vessel Groups Traffic DOWNBOUND

Bridge NO: 150107
Past the point: 38 *

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$D > 12$	19.00	1.00	1.	1.00	76.20	442.00	20762.45	LARGE
2	Free Tugs	18.00			3.01	46.40	149.80	4059.29	
Σ			1.00		4.01				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times0.000733)$.

Note:
* Past point # 38 is located on the dead-end of an inland waterway and, accordingly, only downbound data is available.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 150189
Past the point: 39

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.04	194.57	1.1	171.50	36.41	187.78	450.14	SMALL
2	$6 \geq D > 3$	5.18	128.38	1.1	112.33	69.17	445.97	5565.69	MED
3	$9 \geq D > 6$	8.11	385.13	1.1	336.99	53.57	301.92	4562.80	MED
4	$12 \geq D > 9$	10.79	79.23	1.1	71.21	64.10	269.86	6078.16	LARGE
5	$D > 12$	25.78	1009.96	1.1	881.58	79.66	482.31	33399.79	LARGE
6	Self Propelled Domestic	11.15			1548.54	44.17	230.36	13497.87	5797.69
7	Self Propelled Foreign	22.37			1287.78	42.33	283.33	8697.63	3068.13
Σ			1797.27		4409.93				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.000733)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 150189
Past the point: 39

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.02	258.76	1.2	216.64	44.35	212.65	684.06	SMALL
2	$6 \geq D > 3$	5.14	569.67	1.2	472.39	72.62	427.99	5583.95	MED
3	$9 \geq D > 6$	8.26	329.97	1.2	276.81	51.55	296.21	4483.99	MED
4	$12 \geq D > 9$	10.81	51.15	1.2	43.13	80.84	416.46	11955.43	LARGE
5	$D > 12$	25.95	574.69	1.2	487.43	81.11	503.78	34596.68	LARGE
6	Self Propelled Domestic	8.92			1532.49	43.81	227.31	9683.13	5114.219
7	Self Propelled Foreign	24.78			1303.82	42.33	283.33	9634.65	3067.52
Σ			1784.23		4332.70				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.000733)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 150068
Past the point: 40

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.54	52.93	1.3	40.63	54.60	207.66	1069.11	SMALL
2	$6 \geq D > 3$	4.94	21.51	1.3	16.73	58.04	293.93	3018.56	MED
3	$9 \geq D > 6$	8.05	34.15	1.3	26.29	36.08	193.07	1848.43	MED
4	Self Propelled $4 \geq D > 2$	3.02			3305.74	12.37	40.92	53.71	21.25
5	Self Propelled $6 \geq D > 4$	5.00			289.91	31.98	106.04	550.08	195.44
6	Self Propelled $8 \geq D > 6$	7.34			62.83	35.00	150.00	1249.75	448.35
7	Self Propelled $10 \geq D > 8$	9.00			1.02	39.33	178.67	2052.60	1064.74
Σ			108.59		3743.16				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 150068
Past the point: 40

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.06	47.46	1.1	45.07	36.26	170.05	424.26	SMALL
2	$6 \geq D > 3$	4.94	11.95	1.1	11.27	41.41	185.70	1381.34	MED
3	$9 \geq D > 6$	8.30	38.59	1.1	3.88	46.60	217.72	2883.11	MED
4	Self Propelled $4 \geq D > 2$	3.02			3308.47	12.37	40.83	53.60	21.21
5	Self Propelled $6 \geq D > 4$	5.00			290.01	32.00	106.18	551.70	196.14
6	Self Propelled $8 \geq D > 6$	7.34			62.83	35.00	150.00	1249.75	448.35
7	Self Propelled $10 \geq D > 8$	9.00			0.34	38.00	180.00	1997.31	1050.66
Σ			98.00		3755.11				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

<u>CY2000 Vessel Group Traffic UPBOUND</u>

Bridge NO: 760043
Past the point: 41

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	25.08	1.	25.08	50.02	290.00	941.33	SMALL
2	$6 \geq D > 3$	6.00	148.20	1.	148.20	50.06	279.98	2728.30	MED
3	$9 \geq D > 6$	7.70	71.82	1.	71.82	50.02	282.86	3542.13	MED
4	Free Tugs	7.86			15.96	23.75	63.11	384.52	
5	Self Propelled	5.06			243.96	39.55	95.32	616.64	219.22
6	Other Vessels	8.00			237.12	35.90	96.50	899.21	354.76
Σ			245.10		742.14				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.031)$.

<u>CY2000 Vessel Group Traffic DOWNBOUND</u>

Bridge NO: 760043
Past the point: 41

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	245.10	1.	245.10	50.04	281.85	915.25	SMALL
2	$6 \geq D > 3$	6.00	1.14	1.	1.14	45.00	188.60	1652.16	MED
3	Free Tugs	7.87			13.68	23.78	63.13	385.33	
4	Self Propelled	5.06			243.96	39.55	95.32	616.64	219.22
5	Other Vessels	8.00			237.12	35.90	96.50	899.21	354.76
Σ			246.24		741.00				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.031)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 170064
Past the point: 42

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.73	23.90	1.	23.90	42.80	192.76	467.64	SMALL
2	$6 \geq D > 3$	4.76	5.81	1.	5.81	42.47	172.51	1257.66	MED
3	Free Tugs	7.25			48.15	23.07	67.14	400.65	
4	Self Propelled $4 \geq D > 2$	3.09			3580.28	13.38	45.26	75.60	29.98
5	Self Propelled $6 \geq D > 4$	5.39			633.76	31.48	111.86	618.36	231.18
6	Self Propelled $8 \geq D > 6$	7.00			583.23	35.00	150.00	1192.35	416.65
7	Self Propelled $10 \geq D > 8$	9.00			1.02	39.33	178.67	2052.60	1064.74
Σ			29.71		4876.14				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 170064
Past the point: 42

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.86	11.95	1.	11.95	43.49	182.61	486.32	SMALL
2	$6 \geq D > 3$	5.00	8.20	1.	8.20	43.12	186.38	1514.30	MED
3	$9 \geq D > 6$	8.00	9.56	1.	9.56	42.94	219.20	2480.21	MED
4	Free Tugs	7.19			49.51	25.04	73.91	449.88	
5	Self Propelled $4 \geq D > 2$	3.09			3583.01	13.38	45.17	75.48	29.93
6	Self Propelled $6 \geq D > 4$	5.40			613.62	31.38	110.65	611.29	226.41
7	Self Propelled $8 \geq D > 6$	7.00			583.23	35.00	150.00	1192.35	416.65
8	Self Propelled $10 \geq D > 8$	9.00			0.34	38.00	180.00	1997.31	1050.66
Σ			29.71		4859.75				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 170021
Past the point: 43

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.73	23.90	1.	23.90	42.80	192.76	467.64	SMALL
2	$6 \geq D > 3$	4.76	5.81	1.	5.81	42.47	172.51	1257.66	MED
3	Free Tugs	7.25			48.15	23.07	67.14	400.65	
4	Self Propelled $4 \geq D > 2$	3.09			3580.28	13.38	45.26	75.60	29.98
5	Self Propelled $6 \geq D > 4$	5.39			633.76	31.48	111.86	618.36	231.18
6	Self Propelled $8 \geq D > 6$	7.00			583.23	35.00	150.00	1192.35	416.65
7	Self Propelled $10 \geq D > 8$	9.00			1.02	39.33	178.67	2052.60	1064.74
Σ			29.71		4876.14				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 170021
Past the point: 43

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	1.86	11.95	1.	11.95	43.49	182.61	486.32	SMALL
2	$6 \geq D > 3$	5.00	8.20	1.	8.20	43.12	186.38	1514.30	MED
3	$9 \geq D > 6$	8.00	9.56	1.	9.56	42.94	219.20	2480.21	MED
4	Free Tugs	7.19			49.51	25.04	73.91	449.88	
5	Self Propelled $4 \geq D > 2$	3.09			3583.01	13.38	45.17	75.48	29.93
6	Self Propelled $6 \geq D > 4$	5.40			613.62	31.38	110.65	611.29	226.41
7	Self Propelled $8 \geq D > 6$	7.00			583.23	35.00	150.00	1192.35	416.65
8	Self Propelled $10 \geq D > 8$	9.00			0.34	38.00	180.00	1997.31	1050.66
Σ			29.71		4859.75				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 783080
Past the point: 44

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.04	40.48	1.	40.48	46.98	214.29	717.34	SMALL
2	$6 \geq D > 3$	4.87	19.17	1.	19.17	64.58	247.82	2654.70	MED
3	$9 \geq D > 6$	8.00	1.42	1.	1.42	41.25	187.50	2016.05	MED
4	$12 \geq D > 9$	11.40	3.55	1.	3.55	48.60	203.20	3657.30	LARGE
5	Free Tugs	7.04			28.41	23.09	64.72	384.38	
6	Self Propelled $4 \geq D > 2$	4.00			0.71	24.00	100.00	311.47	215.04
7	Self Propelled $6 \geq D > 4$	5.63			2.84	32.56	139.50	880.65	388.36
8	Self Propelled $10 \geq D > 8$	9.00			1.78	38.00	179.20	1988.44	1037.27
Σ			21.54		32.78				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 783080
Past the point: 44

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.19	26.63	1.	26.63	48.93	222.38	795.80	SMALL
2	$6 \geq D > 3$	5.14	15.62	1.	15.62	60.09	214.06	2221.18	MED
3	$9 \geq D > 6$	7.26	15.27	1.	15.27	53.53	193.93	2642.73	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	6.91			33.38	22.75	63.84	358.14	
6	Self Propelled $4 \geq D > 2$	4.00			1.07	24.00	100.00	311.47	215.04
7	Self Propelled $6 \geq D > 4$	6.00			1.07	33.67	141.40	968.81	450.17
8	Self Propelled $8 \geq D > 6$	7.00			1.78	38.20	165.12	1433.14	520.18
9	Self Propelled $10 \geq D > 8$	9.00			0.71	70.00	456.15	11941.63	13427.22
Σ			58.59		95.87				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 780074
Past the point: 45

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.04	40.48	1.	40.48	46.98	214.29	717.34	SMALL
2	$6 \geq D > 3$	4.87	19.17	1.	19.17	64.58	247.82	2654.70	MED
3	$9 \geq D > 6$	8.00	1.42	1.	1.42	41.25	187.50	2016.05	MED
4	$12 \geq D > 9$	11.40	3.55	1.	3.55	48.60	203.20	3657.30	LARGE
5	Free Tugs	7.04			28.41	23.09	64.72	384.38	
6	Self Propelled $4 \geq D > 2$	4.00			0.71	24.00	100.00	311.47	215.04
7	Self Propelled $6 \geq D > 4$	5.63			2.84	32.56	139.50	880.65	388.36
8	Self Propelled $10 \geq D > 8$	9.00			1.78	38.00	179.20	1988.44	1037.27
Σ			21.54		32.78				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 780074
Past the point: 45

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.19	26.63	1.	26.63	48.93	222.38	795.80	SMALL
2	$6 \geq D > 3$	5.14	15.62	1.	15.62	60.09	214.06	2221.18	MED
3	$9 \geq D > 6$	7.26	15.27	1.	15.27	53.53	193.93	2642.73	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	6.91			33.38	22.75	63.84	358.14	
6	Self Propelled $4 \geq D > 2$	4.00			1.07	24.00	100.00	311.47	215.04
7	Self Propelled $6 \geq D > 4$	6.00			1.07	33.67	141.40	968.81	450.17
8	Self Propelled $8 \geq D > 6$	7.00			1.78	38.20	165.12	1433.14	520.18
9	Self Propelled $10 \geq D > 8$	9.00			0.71	70.00	456.15	11941.63	13427.22
Σ			58.59		95.87				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 780056
Past the point: 46

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.05	2.66	1.	2.66	42.41	223.66	646.60	SMALL
2	$6 \geq D > 3$	5.93	226.76	1.	226.76	46.95	260.39	2404.05	MED
3	$9 \geq D > 6$	7.54	182.02	1.	182.02	44.42	250.00	2797.00	MED
4	$12 \geq D > 9$	10.23	4.94	1.	4.94	39.40	209.25	2830.35	LARGE
5	Free Tugs	7.50			45.98	22.60	61.00	339.21	
6	Self propelled	5.00			1.14	23.33	61.07	278.65	115.06
Σ			443.08		490.20				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.031)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 780056
Past the point: 46

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	439.28	1.	439.28	45.61	253.62	769.13	SMALL
2	$6 \geq D > 3$	4.71	2.66	1.	2.66	37.87	157.67	928.22	MED
3	$9 \geq D > 6$	7.50	1.52	1.	1.52	36.30	165.05	1476.39	MED
4	$12 \geq D > 9$	10.00	1.52	1.	1.52	35.00	195.00	2214.37	LARGE
5	Free Tugs	7.51			42.94	22.61	60.97	339.78	
6	Self Propelled	4.67			1.14	23.33	61.07	237.03	104.87
Σ			444.60		489.06				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.031)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 940094
Past the point: 47

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.05	19.63	1.	19.63	46.76	182.21	637.97	SMALL
2	$6 \geq D > 3$	4.90	18.11	1.	18.11	65.76	250.62	2738.33	MED
3	$9 \geq D > 6$	7.62	4.62	1.	4.62	42.23	199.38	2081.49	MED
4	$12 \geq D > 9$	11.31	10.30	1.	10.30	46.90	199.79	3441.79	LARGE
5	Free Tugs	6.95			26.63	23.64	68.61	414.44	
6	Self Propelled $4 \geq D > 2$	3.50			1.42	17.75	69.95	178.07	105.37
7	Self Propelled $6 \geq D > 4$	5.56			3.20	31.50	135.67	826.33	360.56
8	Self Propelled $10 \geq D > 8$	9.00			1.78	38.00	179.20	1988.44	1037.27
Σ			52.20		85.57				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 940094
Past the point: 47

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.01	30.18	1.	30.18	47.06	200.15	648.95	SMALL
2	$6 \geq D > 3$	4.87	10.65	1.	10.65	69.80	243.62	2742.72	MED
3	$9 \geq D > 6$	7.33	11.72	1.	11.72	57.63	206.79	3029.07	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	6.92			30.54	22.88	65.48	378.26	
6	Self Propelled $4 \geq D > 2$	3.60			1.78	19.00	75.96	204.75	125.65
7	Self Propelled $6 \geq D > 4$	6.00			1.07	33.67	141.40	968.81	450.17
8	Self Propelled $8 \geq D > 6$	7.00			1.78	38.20	165.12	1433.14	520.18
9	Self Propelled $10 \geq D > 8$	9.00			0.71	70.00	456.15	11941.63	13427.22
Σ			53.26		89.12				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 940045
Past the point: 48

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.05	19.63	1.	19.63	46.76	182.21	637.97	SMALL
2	$6 \geq D > 3$	4.90	18.11	1.	18.11	65.76	250.62	2738.33	MED
3	$9 \geq D > 6$	7.62	4.62	1.	4.62	42.23	199.38	2081.49	MED
4	$12 \geq D > 9$	11.31	10.30	1.	10.30	46.90	199.79	3441.79	LARGE
5	Free Tugs	6.95			26.63	23.64	68.61	414.44	
6	Self Propelled $4 \geq D > 2$	3.50			1.42	17.75	69.95	178.07	105.37
7	Self Propelled $6 \geq D > 4$	5.56			3.20	31.50	135.67	826.33	360.56
8	Self Propelled $10 \geq D > 8$	9.00			1.78	38.00	179.20	1988.44	1037.27
Σ			52.20		85.57				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 940045
Past the point: 48

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.01	30.18	1.	30.18	47.06	200.15	648.95	SMALL
2	$6 \geq D > 3$	4.87	10.65	1.	10.65	69.80	243.62	2742.72	MED
3	$9 \geq D > 6$	7.33	11.72	1.	11.72	57.63	206.79	3029.07	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs	6.92			30.54	22.88	65.48	378.26	
6	Self Propelled $4 \geq D > 2$	3.60			1.78	19.00	75.96	204.75	125.65
7	Self Propelled $6 \geq D > 4$	6.00			1.07	33.67	141.40	968.81	450.17
8	Self Propelled $8 \geq D > 6$	7.00			1.78	38.20	165.12	1433.14	520.18
9	Self Propelled $10 \geq D > 8$	9.00			0.71	70.00	456.15	11941.63	13427.22
Σ			53.26		89.12				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 890003
Past the point: 49

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	13.66	1.	13.66	43.75	183.26	520.46	SMALL
2	$6 \geq D > 3$	4.86	7.17	1.	7.17	43.32	179.18	1464.06	MED
3	$9 \geq D > 6$	8.08	4.10	1.	4.10	47.12	227.92	2893.79	MED
4	Free Tugs	7.40			46.10	23.80	70.85	454.44	
5	Self Propelled $2 \geq D$	2.00			28.00	14.00	74.00	67.23	27.84
6	Self Propelled $4 \geq D > 2$	3.00			41.32	14.97	46.94	68.42	27.03
7	Self Propelled $6 \geq D > 4$	5.00			1.02	30.53	134.53	687.11	310.84
8	Self Propelled $10 \geq D > 8$	9.00			0.68	37.30	191.00	2078.08	1043.04
Σ			8.31		47.35				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0058)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 890003
Past the point: 49

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.18	17.07	1.	17.07	42.44	177.86	538.63	SMALL
2	$6 \geq D > 3$	4.58	4.10	1.	4.10	44.78	170.50	1158.48	MED
3	$9 \geq D > 6$	7.00	0.68	1.	0.68	35.00	187.50	1490.44	MED
4	$12 \geq D > 9$	10.00	0.68	1.	0.68	72.00	460.00	10745.78	LARGE
5	Free Tugs	7.78			43.37	23.71	69.10	464.37	
6	Self Propelled $2 \geq D$	2.00			28.34	14.00	74.00	67.23	27.84
7	Self Propelled $4 \geq D > 2$	3.00			41.32	14.97	46.94	68.42	27.03
8	Self Propelled $6 \geq D > 4$	5.00			1.02	25.53	117.53	497.14	207.90
9	Self Propelled $10 \geq D > 8$	9.00			1.02	39.33	178.67	2052.60	1064.74
Σ			22.54		137.61				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times0.0058)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 890060
Past the point: 50

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.05	20.59	1.	20.59	46.67	178.65	622.09	SMALL
2	$6 \geq D > 3$	4.90	18.11	1.	18.11	65.76	250.62	2738.33	MED
3	$9 \geq D > 6$	7.57	4.97	1.	4.97	42.43	193.71	2020.41	MED
4	$12 \geq D > 9$	11.31	10.30	1.	10.30	46.90	199.79	3441.79	LARGE
5	Free Tugs	6.83			36.22	22.94	66.44	384.07	
6	Self Propelled $2 \geq D$	2.00			0.36	14.00	74.00	67.23	27.84
7	Self Propelled $4 \geq D > 2$	3.50			1.42	17.75	69.95	178.07	105.37
8	Self Propelled $6 \geq D > 4$	5.50			2.84	32.19	142.00	875.84	371.46
9	Self Propelled $10 \geq D > 8$	9.00			1.78	38.00	179.20	1988.44	1037.27
Σ			53.97		96.58				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 890060
Past the point: 50

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.00	30.54	1.	30.54	46.82	196.18	629.24	SMALL
2	$6 \geq D > 3$	4.84	11.01	1.	11.01	68.58	239.64	2670.34	MED
3	$9 \geq D > 6$	7.32	12.07	1.	12.07	56.67	203.89	2946.93	MED
4	$12 \geq D > 9$	10.50	0.71	1.	0.71	72.10	250.00	6140.62	LARGE
5	Free Tugs			7.02	38.70	22.67	64.71	377.38	
6	Self Propelled $2 \geq D$	2.00			0.36	14.00	74.00	67.23	27.84
7	Self Propelled $4 \geq D > 2$	3.67			2.13	19.83	79.97	222.54	139.67
8	Self Propelled $6 \geq D > 4$	6.00			0.71	37.50	169.60	1238.10	537.31
9	Self Propelled $8 \geq D > 6$	7.00			0.78	38.20	165.12	1433.14	520.18
10	Self Propelled $10 \geq D > 8$	9.00			0.71	70.00	456.15	11941.63	13427.22
Σ			54.33		98.71				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 794003
Past the point: 51

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT D (FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.06	34.80	1.	34.80	47.81	225.30	769.08	SMALL
2	$6 \geq D > 3$	4.88	18.46	1.	18.46	65.43	251.21	2719.68	MED
3	$9 \geq D > 6$	8.00	1.42	1.	1.42	41.25	187.50	2016.05	MED
4	$12 \geq D > 9$	11.40	3.55	1.	3.55	48.60	203.20	3657.30	LARGE
5	Free Tugs	7.23			22.37	23.51	66.48	412.18	
6	Self Propelled	6.31			5.68	31.88	140.74	1103.44	548.69
Σ			58.23		86.28				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1 + n \times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 794003
Past the point: 51

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** *D* **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.18	25.56	1.	25.56	49.30	225.81	811.92	SMALL
2	$6 \geq D > 3$	4.97	12.43	1.	12.43	64.97	229.67	2492.41	MED
3	$9 \geq D > 6$	7.32	12.78	1.	12.78	55.79	205.86	2931.27	MED
4	Free Tugs	7.10			27.70	23.06	65.02	381.83	
5	Self Propelled	6.14			4.97	36.82	178.71	2495.32	1478.99
Σ			50.78		83.44				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic UPBOUND

Bridge NO: 790172
Past the point: 52

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.06	34.80	1.	34.80	47.81	225.30	769.08	SMALL
2	$6 \geq D > 3$	4.88	18.46	1.	18.46	65.43	251.21	2719.68	MED
3	$9 \geq D > 6$	8.00	1.42	1.	1.42	41.25	187.50	2016.05	MED
4	$12 \geq D > 9$	11.40	3.55	1.	3.55	48.60	203.20	3657.30	LARGE
5	Free Tugs	7.23			22.37	23.51	66.48	412.18	
6	Self Propelled	6.31			5.68	31.88	140.74	1103.44	548.69
Σ			58.23		86.28				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n\times 0.0153)$.

CY2000 Vessel Group Traffic DOWNBOUND

Bridge NO: 790172
Past the point: 52

	A	B	C	D	E	F	G	H	I
GROUP	**VESSEL DRAFT** D **(FT)**	**AVE. DRAFT (FT)**	**NUMBER OF BARGES**	**NUMBER OF BARGES PER TRIP**	**NUMBER OF TRIPS**	**AVE. WIDTH (FT)**	**AVE. LENGTH (FT)**	**AVE. SINGLE UNIT DISPLACEMENT (TON)**	**TUG TYPE Or DWT (TONNE)**
1	$3 \geq D$	2.18	25.56	1.	25.56	49.30	225.81	811.92	SMALL
2	$6 \geq D > 3$	4.97	12.43	1.	12.43	64.97	229.67	2492.41	MED
3	$9 \geq D > 6$	7.32	12.78	1.	12.78	55.79	205.86	2931.27	MED
4	Free Tugs	7.10			27.70	23.06	65.02	381.83	
5	Self Propelled	6.14			4.97	36.82	178.71	2495.32	1478.99
Σ			50.78		83.44				

For future trip projections, annual trips of n years later in excess of 2000 multiply by $(1+n \times 0.0153)$.

APPENDIX IV

DESIGN EXAMPLE BY MATHCAD

VESSEL IMPACT RISK ANALYSIS

EXAMPLE BRIDGE on past point # 03 upbound
Consider a total number of 14 brdige piers on both sides of channel.
Use barge group data in the project's final report to describe the vessel configurations in 2050.
Transit velocities of each vessel group are based on Table 6 in the project's final report.

DESIGNER: Liu, Chunhua

NO.:
SHEET: 1 of 13

DATE:18/01/99

Units: feet and tonnes as per 1991 AASHTO Vessel Collision Guide Specification.

DESIGN FOR BARGE & SHIP IMPACT TO SUBSTRUCTURE

Number of Piers   Piers := 14   j := 1.. Piers

Determine the Bridge Characteristics:

Importance Classification (IC) (Section 3.3): Critical Bridge, Acceptable Risk of Bridge Collapse = .0001
(A return period of 1 in 10,000 years)

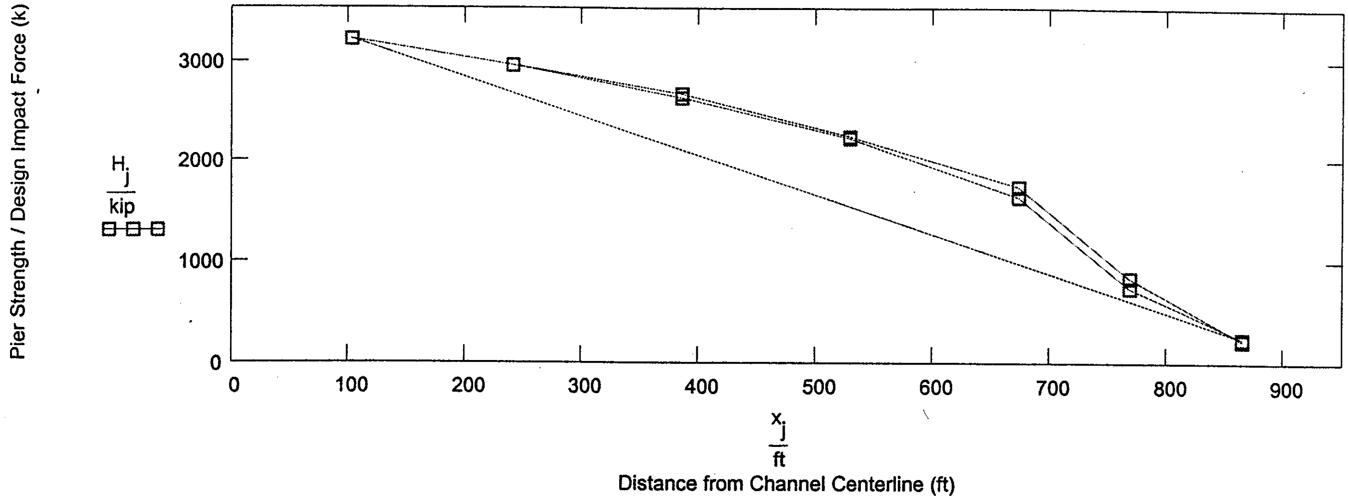
Bp= Bridge pier width, considering angle between channel and bridge centerline.

H = Ultimate horizontal substructure strength.

x = Distance from the centerline of channel to the centerline of the pier.

Note: The subscript " j " refers to the row number of the pier value in the input tables in MathCad. The piers are arranged in the tables corresponding to one side of the channel (double the risk):

		j	$x_j :=$	$BP_j :=$	$H_j :=$
Row 1 -	Pier 1	1	102·ft	30·ft	3230·kip
Row 2 -	Pier 2	2	240·ft	40·ft	2960·kip
Row 3 -	Pier 3	3	384·ft	40·ft	2650·kip
Row 4 -	Pier 4	4	528·ft	40·ft	2250·kip
Row 5 -	Pier 5	5	672·ft	40·ft	1650·kip
Row 6 -	Pier 6	6	768·ft	40·ft	750·kip
Row 7 -	Pier 7	7	864·ft	40·ft	240·kip
Row 8 -	Pier 8	8	102·ft	30·ft	3230·kip
Row 9 -	Pier 9	9	240·ft	40·ft	2960·kip
Row 10 -	Pier 10	10	384·ft	40·ft	2680·kip
Row 11 -	Pier 11	11	528·ft	40·ft	2270·kip
Row 12 -	Pier 12	12	672·ft	40·ft	1750·kip
Row 13 -	Pier 13	13	768·ft	40·ft	850·kip
Row 14 -	Pier 14	14	864·ft	40·ft	230·kip



Determine Navigable Channel Characteristics (Sections 3.4 & 4.2):

j = Pier number

D_w = Water Depth from existing mudline to mean high water (Section 4.2.2).

C = Channel width as shown on Figures 4.2.1-1, 4.2.1-2, and 8.5.1-1. $C := 125 \cdot ft$

θ = Angle of channel turn or bend as shown in Figure 4.8.3.2-1. $\theta := 0 \cdot deg$

region = Waterway region as shown in Figure 4.8.3.2-1
[1 = Straight, 2 = Transition, 3 = Turn/Bend]. region := 1

V_c = Waterway current component acting parallel to the vessel transit path. $V_c := 0.6756 \cdot \frac{ft}{sec}$

V_{XC} = Waterway current component acting perpendicular to the vessel transit path. $V_{XC} := 0. \cdot \frac{ft}{sec}$

j	$D_{w_j} :=$
1	12·ft
2	12·ft
3	10·ft
4	10·ft
5	10·ft
6	8·ft
7	8·ft
8	16·ft
9	16·ft
10	13·ft
11	13·ft
12	13·ft
13	10·ft
14	10·ft

Determine Vessel Transit Path (Section 4.2.1):

Vessel transit path as shown in Figure 4.2.1-2 (and Figure 3.7-1 for impact speed distribution).

For this project bridge the centerline of vessel transit path is the same as the centerline of the channel, therefore the distance " x " shown above is the distance from the center of each bridge pier to the centerline of vessel transit path.

x_C = Distance from edge of channel to centerline of vessel transit path. $x_C := 62.5 \cdot ft$
(Use one-half of the channel width).

Determine Vessel Fleet Characteristics Sections (3.5 & 4.4):

Number of different Self Propelled Vessels $SPTypes := 5$ $t := 1 .. SPTypes$

Wp = displacement of tug, ferry, etc

Dp = Draft of tug,ferry, etc

Bp = Width of tug, ferry, etc

Lp = Length of tug, ferry, etc

t	$Wp_t :=$	$Dp_t :=$	$Bp_t :=$	$Lp_t :=$
1	65·ton	4.0·ft	20·ft	50·ft
2	130·ton	7.0·ft	30·ft	100·ft
3	220·ton	9.0·ft	35·ft	120·ft
4	413.10·ton	7.0·ft	23.64·ft	68.70·ft
5	575.00·ton	6.24·ft	31.35·ft	138.64·ft

Vessel Characteristics and Configuation $Vessels := 6$ $i := 1 .. Vessels$

VT = vessel speed in channel

Db = Draft of barge

Bb = Width of barge

Lb = Length of a single barge

NB = number of barges long (*0 for none*)

Wb = displacement of barge

SPT = Power Type
(defined above, 0 for none)

N_i = number of trips

i	$V_{T_i} :=$	$Db_i :=$	$Bb_i :=$	$Lb_i :=$	$NB_i :=$	$Wb_i :=$	SPT_i	$N_i :=$
1	6.6·knot	2.05·ft	46.61·ft	176.19·ft	1	611.57·ton	1	37.59
2	6.6·knot	4.87·ft	64.55·ft	246.30·ft	1	2659.30·ton	2	33.22
3	6.6·knot	7.62·ft	42.23·ft	199.38·ft	1	2081.49·ton	2	8.15
4	6.6·knot	11.31·ft	46.90·ft	199.79·ft	1	3441.79·ton	3	18.18
5	9.6·knot	7.0·ft	23.64·ft	68.70·ft	1	413.10·ton	4	49.51
6	9.6·knot	0·ft	0·ft	0·ft	0	575.00·ton	5	10.66

Annual No. of Vessel Transits $\Sigma N = 157.31$

B_B = vessel width

$$B_{B_i} := \mathrm{if}\left[NB_i > 0, Bb_i, Bp_{(SPT_i)}\right]$$

$$B_B^T = [\,46.61 \quad 64.55 \quad 42.23 \quad 46.9 \quad 23.64 \quad 31.35\,] \cdot ft$$

D_{Lt} = power vessel draft

$$D_{Lp_i} := \mathrm{if}\left[SPT_i = 0, 0 \cdot ft, Dp_{(SPT_i)}\right]$$

$$D_{Lp}^T = [\,4 \quad 7 \quad 7 \quad 9 \quad 7 \quad 6.24\,] \cdot ft$$

D_{Lb} = barge draft

$$D_{Lb_i} := \mathrm{if}\left(NB_i = 0, 0 \cdot ft, Db_i\right)$$

$$D_{Lb}^T = [\,2.05 \quad 4.87 \quad 7.62 \quad 11.31 \quad 7 \quad 0\,] \cdot ft$$

D_{Lv} = vessel draft

$$D_{Lv_i} := \mathrm{if}\left(D_{Lp_i} > D_{Lb_i}, D_{Lp_i}, D_{Lb_i}\right)$$

$$D_{Lv}^T = [\,4 \quad 7 \quad 7.62 \quad 11.31 \quad 7 \quad 6.24\,] \cdot ft$$

LOA = length overall

$$LOA_i := Lb_i \cdot NB_i + \mathrm{if}\left[SPT_i > 0, Lp_{(SPT_i)}, 0 \cdot ft\right]$$

$$LOA^T = [\,226.19 \quad 346.3 \quad 299.38 \quad 319.79 \quad 137.4 \quad 138.64\,] \cdot ft$$

As vessel becomes abberant, tug will separate when tug draft = water depth and the barge group will separate into individual barg

case 1 - barge group intact (tug draft > water depth) case 2 - abberrant barge, use one barge w/o tug (tug draft < water depth)

D_L = Draft of barge or vessel (ft) $$D_{L_{i,j}} := \mathrm{if}\left(D_{w_j} > D_{Lv_i}, D_{Lv_i}, \mathrm{if}\left(D_{w_j} > D_{Lb_i}, D_{Lb_i}, 0\cdot ft\right)\right)$$

$$D_L = \begin{bmatrix} 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 \\ 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 \\ 7.62 & 7.62 & 7.62 & 7.62 & 7.62 & 7.62 & 7.62 & 7.62 & 7.62 & 7.62 & 7.62 & 7.62 & 7.62 & 7.62 \\ 11.31 & 11.31 & 0 & 0 & 0 & 0 & 0 & 11.31 & 11.31 & 11.31 & 11.31 & 11.31 & 0 & 0 \\ 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 \\ 6.24 & 6.24 & 6.24 & 6.24 & 6.24 & 6.24 & 6.24 & 6.24 & 6.24 & 6.24 & 6.24 & 6.24 & 6.24 & 6.24 \end{bmatrix} \cdot ft$$

$$D_w^T = \begin{bmatrix} 12 & 12 & 10 & 10 & 10 & 8 & 8 & 16 & 16 & 13 & 13 & 13 & 10 & 10 \end{bmatrix} \cdot ft$$

WLv = vessel displacement assumming only one column of barges will impact the pier $$WLv_i := Wb_i \cdot NB_i + \mathrm{if}\left(SPT_i > 0, Wp_{SPT_i}, 0\cdot tonne\right)$$

W = displacement of vessel $$W_{i,j} := \mathrm{if}\left(D_{w_j} > D_{Lv_i}, WLv_i, \mathrm{if}\left(D_{w_j} > D_{Lb_i}, Wb_i, .001\cdot tonne\right)\right)$$

$$W = \begin{bmatrix} 0.614 & 0.614 & 0.614 & 0.614 & 0.614 & 0.614 & 0.614 & 0.614 & 0.614 & 0.614 & 0.614 & 0.614 & 0.614 & 0.614 \\ 2.53 & 2.53 & 2.53 & 2.53 & 2.53 & 2.53 & 2.53 & 2.53 & 2.53 & 2.53 & 2.53 & 2.53 & 2.53 & 2.53 \\ 2.006 & 2.006 & 2.006 & 2.006 & 2.006 & 2.006 & 2.006 & 2.006 & 2.006 & 2.006 & 2.006 & 2.006 & 2.006 & 2.006 \\ 3.321 & 3.321 & 0 & 0 & 0 & 0 & 0 & 3.321 & 3.321 & 3.321 & 3.321 & 3.321 & 0 & 0 \\ 0.749 & 0.749 & 0.749 & 0.749 & 0.749 & 0.749 & 0.749 & 0.749 & 0.749 & 0.749 & 0.749 & 0.749 & 0.749 & 0.749 \\ 0.522 & 0.522 & 0.522 & 0.522 & 0.522 & 0.522 & 0.522 & 0.522 & 0.522 & 0.522 & 0.522 & 0.522 & 0.522 & 0.522 \end{bmatrix} \circ 10^3 \cdot tonne$$

Determine Design Impact Speed (V) (Section 3.7):

V_{min} = The minimum impact speed, Vmin, at 3xLOA is equal to the yearly mean current of Croatan Sound.

$$V_{min} := 0.4 \cdot knot$$

x_L = Distance equal to 3xLOA from centerline of vessel transit path

$$x_{L_i} := 3 \cdot LOA_i$$

x_{L_i} (ft)
678.57
1038.9
898.14
959.37
412.2
415.92

Note: The 3xLOA is computed for each vessel category. (The use of a single LOA based on the Method I design vessel, was a simplification included in the AASHTO Guide Spec to reduce the hand computation effort).

s = transition slope between V_T and V_{min}

$$s_{i,j} := \frac{V_{T_i} - V_{min}}{x_{L_i} - x_C}$$

V = design impact velocity

$$V_{i,j} := \text{if}\left[x_j \le x_C, V_{T_i}, \text{if}\left[x_j \le x_{L_i}, V_{T_i} - (x_j - x_C) \cdot s_{i,j}, V_{min}\right]\right]$$

$$V = \begin{bmatrix} 10.48 & 8.13 & 5.68 & 3.23 & 0.79 & 0.68 & 0.68 & 10.48 & 8.13 & 5.68 & 3.23 & 0.79 & 0.68 & 0.68 \\ 10.72 & 9.24 & 7.7 & 6.15 & 4.61 & 3.58 & 2.55 & 10.72 & 9.24 & 7.7 & 6.15 & 4.61 & 3.58 & 2.55 \\ 10.65 & 8.92 & 7.12 & 5.31 & 3.51 & 2.31 & 1.1 & 10.65 & 8.92 & 7.12 & 5.31 & 3.51 & 2.31 & 1.1 \\ 10.69 & 9.07 & 7.39 & 5.71 & 4.03 & 2.91 & 1.79 & 10.69 & 9.07 & 7.39 & 5.71 & 4.03 & 2.91 & 1.79 \\ 14.46 & 8.33 & 1.93 & 0.68 & 0.68 & 0.68 & 0.68 & 14.46 & 8.33 & 1.93 & 0.68 & 0.68 & 0.68 & 0.68 \\ 14.48 & 8.41 & 2.08 & 0.68 & 0.68 & 0.68 & 0.68 & 14.48 & 8.41 & 2.08 & 0.68 & 0.68 & 0.68 & 0.68 \end{bmatrix} \circ \frac{ft}{sec}$$

Vessel Impact Speeds at each Bridge Pier

Determine Probability of Aberrancy (PA) (Section 4.8.3.2):

BR = Aberrancy base rate (barges):

$$BR_i := \begin{vmatrix} 1.2 \cdot 10^{-4} \text{ if } NB_i \ne 0 & \text{for barges} \\ 0.6 \cdot 10^{-4} \text{ if } NB_i = 0 & \text{for ships} \end{vmatrix}$$

R_B = Correction factor for bridge location:

$$R_B := \text{if}\left(\text{region}=1, 1, \text{if}\left(\text{region}=2, 1 + \frac{\theta}{90 \cdot deg}, 1 + \frac{\theta}{45 \cdot deg}\right)\right) \qquad R_B = 1$$

R_C = Correction factor for currents acting parallel to vessel transit path:

$$R_C := 1 + \frac{V_c}{16.89 \cdot \frac{ft}{sec}} \qquad R_C = 1.04$$

(Note: Eqs for Rc and Rxc were modified to convert from knots to fps)

R_{XC} = Correction factor for crosscurrents acting perpendicular to vessel transit path:

$$R_{XC} := 1 + \frac{V_{XC}}{1.689 \cdot \frac{ft}{sec}} \qquad R_{XC} = 1$$

R_D = Correction factor for vessel traffic density:

$$R_D := 1$$

PA = Probability of Abberrancy

$$PA_i := BR_i \cdot (R_B) \cdot (R_C) \cdot (R_{XC}) \cdot (R_D)$$

$$PA^T = [\ 0.0001248 \quad 0.0001248 \quad 0.0001248 \quad 0.0001248 \quad 0.0001248 \quad 0.0000624\ ]$$

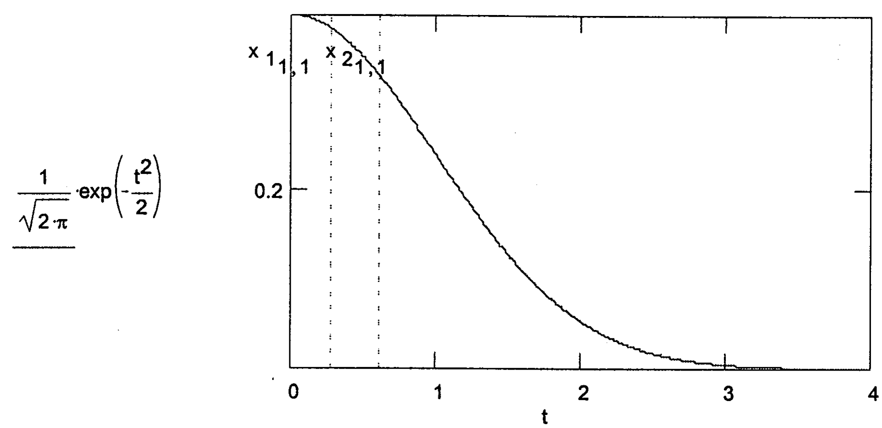
Determine Geometric Probability (PG) (Section 4.8.3.3):

$$x1_{i,j} := \frac{x_j - \frac{BP_j + BB_i}{2}}{(LOA_i)} \qquad x2_{i,j} := \frac{x_j + \frac{BP_j + BB_i}{2}}{(LOA_i)}$$

PG = Geometric Probability

$$PG_{i,j} := \mathrm{cnorm}\left(x2_{i,j}\right) - \mathrm{cnorm}\left(x1_{i,j}\right) \qquad t := 0, .01 .. 4$$

$$PG = \begin{bmatrix} 0.122 & 0.087 & 0.037 & 0.01 & 0.002 & 0.001 & 0 & 0.122 & 0.087 & 0.037 & 0.01 & 0.002 & 0.001 & 0 \\ 0.104 & 0.095 & 0.065 & 0.038 & 0.019 & 0.01 & 0.005 & 0.104 & 0.095 & 0.065 & 0.038 & 0.019 & 0.01 & 0.005 \\ 0.091 & 0.079 & 0.048 & 0.023 & 0.009 & 0.004 & 0.002 & 0.091 & 0.079 & 0.048 & 0.023 & 0.009 & 0.004 & 0.002 \\ 0.091 & 0.082 & 0.053 & 0.028 & 0.012 & 0.006 & 0.003 & 0.091 & 0.082 & 0.053 & 0.028 & 0.012 & 0.006 & 0.003 \\ 0.118 & 0.041 & 0.004 & 0 & 0 & 0 & 0 & 0.118 & 0.041 & 0.004 & 0 & 0 & 0 & 0 \\ 0.134 & 0.047 & 0.005 & 0 & 0 & 0 & 0 & 0.134 & 0.047 & 0.005 & 0 & 0 & 0 & 0 \end{bmatrix}$$



Channel pier impact width location on 'bell curve' for first barge group.

Determine Vessel Collision Energy (KE) (Section 3.8):

UK = Underkeel clearance

$$UK_{c_{i,j}} := \mathrm{if}\left(D_{L_{i,j}} > 0\cdot ft, D_{w_j} - D_{L_{i,j}}, 0\cdot ft\right)$$

C_H = Hydrodynamic mass coefficient:

$$C_{H_{i,j}} := \mathrm{if}\left(UK_{c_{i,j}} \ge 0.5\cdot D_{L_{i,j}}, 1.05, \mathrm{if}\left(UK_{c_{i,j}} \le 0.10\cdot D_{L_{i,j}}, 1.25, 1.05 + \frac{.5\cdot D_{L_{i,j}} - UK_{c_{i,j}}}{.5\cdot D_{L_{i,j}} - .1\cdot D_{L_{i,j}}}\cdot .2\right)\right)$$

KE = Vessel Collision Energy

$$KE_{i,j} := \frac{C_{H_{i,j}}\cdot W_{i,j}\cdot \left(V_{i,j}\right)^2}{2\cdot g}$$

$$C_H = \begin{bmatrix} 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 \\ 1.05 & 1.05 & 1.086 & 1.086 & 1.086 & 1.229 & 1.229 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.086 & 1.086 \\ 1.05 & 1.05 & 1.144 & 1.144 & 1.144 & 1.25 & 1.25 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.144 & 1.144 \\ 1.25 & 1.25 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.093 & 1.093 & 1.225 & 1.225 & 1.225 & 1.05 & 1.05 \\ 1.05 & 1.05 & 1.086 & 1.086 & 1.086 & 1.229 & 1.229 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.086 & 1.086 \\ 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.159 & 1.159 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 \end{bmatrix}$$

$$KE = \begin{bmatrix} 2423 & 1460 & 713 & 231 & 14 & 10 & 10 & 2423 & 1460 & 713 & 231 & 14 & 10 & 10 \\ 10468 & 7778 & 5580 & 3566 & 2001 & 1366 & 693 & 10468 & 7778 & 5396 & 3448 & 1935 & 1207 & 613 \\ 8190 & 5746 & 3984 & 2220 & 968 & 457 & 105 & 8190 & 5746 & 3657 & 2038 & 889 & 418 & 96 \\ 16246 & 11716 & 0 & 0 & 0 & 0 & 0 & 14201 & 10241 & 7623 & 4550 & 2266 & 0 & 0 \\ 5637 & 1870 & 104 & 13 & 13 & 14 & 14 & 5637 & 1870 & 100 & 12 & 12 & 13 & 13 \\ 3933 & 1327 & 81 & 9 & 9 & 9 & 9 & 3933 & 1327 & 81 & 9 & 9 & 9 & 9 \end{bmatrix} \circ kip \cdot ft$$

Determine Ship Collision Force on Pier (P_B) (Section 3.9):

The Ship collision force on the piers (P_S) (Section

DWT = Deadweight tonnage of ship

$$DWT_i := if\left[NB_i = 0, Wp_{(SPT_i)}, 0 \cdot tonne\right]$$

P_S = Ship Collision Force

$$P_{S_{i,j}} := (220) \cdot \sqrt{\frac{DWT_i}{tonne}} \cdot \left(\frac{V_{i,j}}{27}\right) \cdot \left(\frac{sec \cdot kip}{ft}\right) \qquad max\left(P_S\right) = 2694.03525994 \circ kip$$

Determine Barge Collision Force on Pier (P_B) (Section 3.12):

Determine the Barge Bow Damage Depth a_B (Section 3.13):

a_B = Barge Bow Damage Depth

$$a_{B_{i,j}} := \left[\sqrt{\left[1 + \frac{KE_{i,j}}{(5672 \cdot (kip \cdot ft))}\right]} - 1\right] \cdot \left[\frac{10.2 \cdot ft}{\left(\frac{B_{B_i}}{35 \cdot ft}\right)}\right]$$

The barge collision force on the piers (P_B)

P_B = Barge Collision Force

$$P_{B_{i,j}} := if\left[a_{B_{i,j}} < 0.34 \cdot ft, \left(4112 \cdot \frac{kip}{ft}\right) \cdot \left(a_{B_{i,j}}\right) \cdot \left(\frac{B_{B_i}}{35 \cdot ft}\right), \left[1349 \cdot (kip) + \left(110 \cdot \frac{kip}{ft}\right) \cdot \left(a_{B_{i,j}}\right)\right] \cdot \frac{B_{B_i}}{35 \cdot ft}\right]$$

$$P_B = \begin{bmatrix} 2015 & 1933 & 1865 & 846 & 51 & 37 & 37 & 2015 & 1933 & 1865 & 846 & 51 & 37 & 37 \\ 3259 & 3094 & 2946 & 2798 & 2671 & 2616 & 2490 & 3259 & 3094 & 2933 & 2789 & 2665 & 2602 & 2207 \\ 2260 & 2098 & 1970 & 1829 & 1720 & 1657 & 385 & 2260 & 2098 & 1945 & 1814 & 1712 & 1519 & 352 \\ 2891 & 2650 & 0 & 0 & 0 & 0 & 0 & 2786 & 2565 & 2403 & 2192 & 2013 & 0 & 0 \\ 1373 & 1083 & 382 & 47 & 47 & 53 & 53 & 1373 & 1083 & 369 & 45 & 45 & 47 & 47 \\ 1546 & 1333 & 299 & 32 & 32 & 35 & 35 & 1546 & 1333 & 299 & 32 & 32 & 32 & 32 \end{bmatrix} \circ kip$$

Use Ship Collision Force if Number of Barges = 0, otherwise use Barge Collision Force

$$P_{i,j} := \text{if}\left(NB_i = 0, P_{S_{i,j}}, P_{B_{i,j}}\right)$$

Determine Probability of Collapse (PC) (Section 4.8.3.4):

case 1 : For $0.0 \le \frac{H}{P}$ and $\frac{H}{P} \le 0.1$ $\qquad PC1_{i,j} := 0.1 + 9 \cdot \left(.1 - \frac{H_j}{P_{i,j}}\right)$

case 2: For $0.1 \le \frac{H}{P}$ and $\frac{H}{P} \le 1.0$ $\qquad PC2_{i,j} := \frac{\left(1 - \frac{H_j}{P_{i,j}}\right)}{9}$

case3: For $\frac{H}{P} \ge 1.0$ $\qquad PC3_{i,j} := 1 \cdot 10^{-99}$

PC = Probability of Collapse

$$PC_{i,j} := \text{if}\left(\frac{H_j}{P_{i,j}} < 0.1, PC1_{i,j}, \text{if}\left(\frac{H_j}{P_{i,j}} < 1.0, PC2_{i,j}, PC3_{i,j}\right)\right)$$

$$PC = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.001 & 0.005 & 0.011 & 0.022 & 0.042 & 0.079 & 0.132 & 0.001 & 0.005 & 0.01 & 0.021 & 0.038 & 0.075 & 0.1 \\ 0 & 0 & 0 & 0 & 0.005 & 0.061 & 0.042 & 0 & 0 & 0 & 0 & 0 & 0.049 & 0.039 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.015 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Determine the Calculated Annual Frequency of Collapse (AFc) (Section 4.8.3):

PS = PROBABILITY OF SCOUR

$PS := 1$

AFc = Annual Frequency of Collapse per vessel per pier

$AFc_{i,j} := (N_i)\cdot(PA_i)\cdot(PG_{i,j})\cdot(PC_{i,j})\cdot(PS)$

SumAFc = Annual Frequency of Collapse per pier

$$SumAFc_j := \sum_{i=1}^{Vessels} AFc_{i,j}$$

Total = Annual Frequency of Collapse

$$TotalAFc := \sum_{j=1}^{Piers} SumAFc_j$$

ReturnPeriod = number of years between collapse events

$$ReturnPeriod := \frac{1}{\displaystyle\sum_{j=1}^{Piers} SumAFc_j}$$

The total bridge return period for these 13 piers (in years) is:

$ReturnPeriod = 27745$

%Risk = percentage of the total risk for each pier

$$\%Risk_j := \frac{SumAFc_j}{TotalAFc}\cdot 100$$

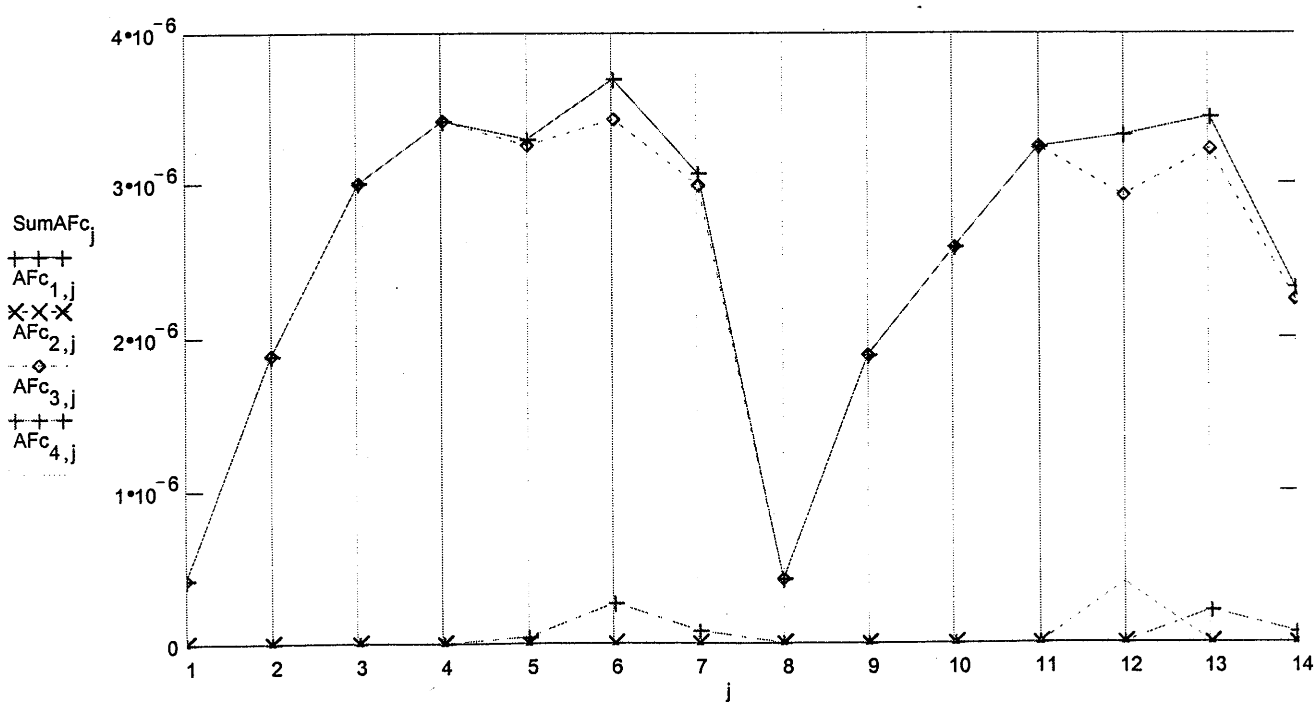
Total% = total risk percentage (should equal 100 percent)

$$Total\% := \sum_{j=1}^{Piers} \%Risk_j$$

$Total\% = 100$

$TotalAFc = 0.00003604$

Pier No.	$SumAFc_j$
1	0.00000042
2	0.00000188
3	0.00000302
4	0.00000341
5	0.0000033
6	0.00000369
7	0.00000307
8	0.00000042
9	0.00000188
10	0.00000259
11	0.00000324
12	0.00000333
13	0.00000345
14	0.00000232



DESIGN SUMMARY

Barge and Pier Data

LOA_i (ft)	N_i	H_j (kip)	Dw_j (ft)	x_j (ft)	BP_j (ft)
226.19	37.59	3230	12	102	30
346.3	33.22	2960	12	240	40
299.38	8.15	2650	10	384	40
319.79	18.18	2250	10	528	40
137.4	49.51	1650	10	672	40
138.64	10.66	750	8	768	40
		240	8	864	40
		3230	16	102	30
		2960	16	240	40
		2680	13	384	40
		2270	13	528	40
		1750	13	672	40
		850	10	768	40
		230	10	864	40

W = barge + Tug + cargo
LOA= length of vessel
N= number of one way passages the barge makes in a year
H= pier ultimate strength
Dw= water depth
x= distance center line channel to center line pier
Bp= pier width
V= velocity of the barge at this pier
PG= geometric probability that this pier may be 'hit'
KE= kinetic energy of vessel and hydrodynamic mass
aB= depth of damage to barge
PB= force from an impact with this pier
PC=probability of collapse if hit
AF= probability of collapse taking all factors into account.

Geometric & Probability Variables

$$V = \begin{bmatrix} 10.48 & 8.13 & 5.68 & 3.23 & 0.79 & 0.68 & 0.68 & 10.48 & 8.13 & 5.68 & 3.23 & 0.79 & 0.68 & 0.68 \\ 10.72 & 9.24 & 7.7 & 6.15 & 4.61 & 3.58 & 2.55 & 10.72 & 9.24 & 7.7 & 6.15 & 4.61 & 3.58 & 2.55 \\ 10.65 & 8.92 & 7.12 & 5.31 & 3.51 & 2.31 & 1.1 & 10.65 & 8.92 & 7.12 & 5.31 & 3.51 & 2.31 & 1.1 \\ 10.69 & 9.07 & 7.39 & 5.71 & 4.03 & 2.91 & 1.79 & 10.69 & 9.07 & 7.39 & 5.71 & 4.03 & 2.91 & 1.79 \\ 14.46 & 8.33 & 1.93 & 0.68 & 0.68 & 0.68 & 0.68 & 14.46 & 8.33 & 1.93 & 0.68 & 0.68 & 0.68 & 0.68 \\ 14.48 & 8.41 & 2.08 & 0.68 & 0.68 & 0.68 & 0.68 & 14.48 & 8.41 & 2.08 & 0.68 & 0.68 & 0.68 & 0.68 \end{bmatrix} \cdot \frac{ft}{sec}$$

$$a_B = \begin{bmatrix} 1.49 & 0.93 & 0.47 & 0.15 & 0.01 & 0.01 & 0.01 & 1.49 & 0.93 & 0.47 & 0.15 & 0.01 & 0.01 & 0.01 \\ 3.8 & 2.99 & 2.26 & 1.53 & 0.9 & 0.63 & 0.33 & 3.8 & 2.99 & 2.2 & 1.48 & 0.87 & 0.56 & 0.29 \\ 4.76 & 3.54 & 2.58 & 1.52 & 0.69 & 0.33 & 0.08 & 4.76 & 3.54 & 2.39 & 1.4 & 0.64 & 0.31 & 0.07 \\ 7.35 & 5.72 & 0 & 0 & 0 & 0 & 0 & 6.64 & 5.14 & 4.04 & 2.61 & 1.39 & 0 & 0 \\ 6.22 & 2.31 & 0.14 & 0.02 & 0.02 & 0.02 & 0.02 & 6.22 & 2.31 & 0.13 & 0.02 & 0.02 & 0.02 & 0.02 \\ 3.43 & 1.26 & 0.08 & 0.01 & 0.01 & 0.01 & 0.01 & 3.43 & 1.26 & 0.08 & 0.01 & 0.01 & 0.01 & 0.01 \end{bmatrix} \cdot ft$$

$$
KE = \begin{bmatrix}
2423 & 1460 & 713 & 231 & 14 & 10 & 10 & 2423 & 1460 & 713 & 231 & 14 & 10 & 10 \\
10468 & 7778 & 5580 & 3566 & 2001 & 1366 & 693 & 10468 & 7778 & 5396 & 3448 & 1935 & 1207 & 613 \\
8190 & 5746 & 3984 & 2220 & 968 & 457 & 105 & 8190 & 5746 & 3657 & 2038 & 889 & 418 & 96 \\
16246 & 11716 & 0 & 0 & 0 & 0 & 0 & 14201 & 10241 & 7623 & 4550 & 2266 & 0 & 0 \\
5637 & 1870 & 104 & 13 & 13 & 14 & 14 & 5637 & 1870 & 100 & 12 & 12 & 13 & 13 \\
3933 & 1327 & 81 & 9 & 9 & 9 & 9 & 3933 & 1327 & 81 & 9 & 9 & 9 & 9
\end{bmatrix} \circ kip \cdot ft
$$

$$
PG = \begin{bmatrix}
0.122 & 0.087 & 0.037 & 0.01 & 0.002 & 0.001 & 0 & 0.122 & 0.087 & 0.037 & 0.01 & 0.002 & 0.001 & 0 \\
0.104 & 0.095 & 0.065 & 0.038 & 0.019 & 0.01 & 0.005 & 0.104 & 0.095 & 0.065 & 0.038 & 0.019 & 0.01 & 0.005 \\
0.091 & 0.079 & 0.048 & 0.023 & 0.009 & 0.004 & 0.002 & 0.091 & 0.079 & 0.048 & 0.023 & 0.009 & 0.004 & 0.002 \\
0.091 & 0.082 & 0.053 & 0.028 & 0.012 & 0.006 & 0.003 & 0.091 & 0.082 & 0.053 & 0.028 & 0.012 & 0.006 & 0.003 \\
0.118 & 0.041 & 0.004 & 0 & 0 & 0 & 0 & 0.118 & 0.041 & 0.004 & 0 & 0 & 0 & 0 \\
0.134 & 0.047 & 0.005 & 0 & 0 & 0 & 0 & 0.134 & 0.047 & 0.005 & 0 & 0 & 0 & 0
\end{bmatrix}
$$

$$
PC = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.001 & 0.005 & 0.011 & 0.022 & 0.042 & 0.079 & 0.132 & 0.001 & 0.005 & 0.01 & 0.021 & 0.038 & 0.075 & 0.1 \\
0 & 0 & 0 & 0 & 0.005 & 0.061 & 0.042 & 0 & 0 & 0 & 0 & 0 & 0.049 & 0.039 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.015 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
$$

$$
P_B = \begin{bmatrix}
2015 & 1933 & 1865 & 846 & 51 & 37 & 37 & 2015 & 1933 & 1865 & 846 & 51 & 37 & 37 \\
3259 & 3094 & 2946 & 2798 & 2671 & 2616 & 2490 & 3259 & 3094 & 2933 & 2789 & 2665 & 2602 & 2207 \\
2260 & 2098 & 1970 & 1829 & 1720 & 1657 & 385 & 2260 & 2098 & 1945 & 1814 & 1712 & 1519 & 352 \\
2891 & 2650 & 0 & 0 & 0 & 0 & 0 & 2786 & 2565 & 2403 & 2192 & 2013 & 0 & 0 \\
1373 & 1083 & 382 & 47 & 47 & 53 & 53 & 1373 & 1083 & 369 & 45 & 45 & 47 & 47 \\
1546 & 1333 & 299 & 32 & 32 & 35 & 35 & 1546 & 1333 & 299 & 32 & 32 & 32 & 32
\end{bmatrix} \circ kip
$$

Determine MINIMUM Barge Collision Force on Pier (P_B) (Section 3.12):

$D_{w_i} := 10 \cdot ft$	Design water depth	
$d_{L_i} := 2 \cdot ft$	The empty barge draft	
$w_i := 181.4 \cdot tonne$	An empty 35x195 foot hopper barge displacement	$200 \cdot ton = 181.4 \cdot tonne$
$V_{min} := 0.4 \cdot knot$	The drifting barge impact speed = annual mean current	$1 \cdot knot = 1.689 \cdot \frac{ft}{sec}$

First, Determine Barge Collision Energy (KE) (Section 3.8):

UK = Underkeel clearance: $UK_{c_{i,j}} := D_{w_i} - d_{L_i}$

CH = Hydrodynamic mass coefficient:

$$C_{H_{i,j}} := if\left(UK_{c_{i,j}} \geq 0.5 \cdot d_{L_i}, 1.05, if\left(UK_{c_{i,j}} \leq 0.10 \cdot d_{L_i}, 1.25, 1.05 + \frac{.5 \cdot d_{L_i} - UK_{c_{i,j}}}{.5 \cdot d_{L_i} - .1 \cdot d_{L_i}} \cdot .2\right)\right)$$

KE_{min} = Barge MIN Collision Energy

$$KE_{min_{i,j}} := \frac{C_{H_{i,j}} \cdot w_i \cdot (V_{min})^2}{2 \cdot g}$$

$max(KE_{min}) = 3 \cdot ft \cdot kip$

$min(KE_{min}) = 3 \cdot ft \cdot kip$

Second, Determine the MINIMUM Barge Bow Damage Depth a_B (Section 3.13):

$$a_{min_{i,j}} := \left[\sqrt{1 + \frac{KE_{min_{i,j}}}{5672 \cdot (kip \cdot ft)}} - 1\right] \cdot \left[\frac{10.2 \cdot ft}{\left(\frac{B_{B_i}}{35 \cdot ft}\right)}\right]$$

$max(a_{min}) = 0.004 \cdot ft$

$min(a_{min}) = 0.0015 \cdot ft$

The MINIMUM barge collision force on the pier (P_B) is then:

$$P_{min_{i,j}} := if\left[a_{min_{i,j}} < 0.34 \cdot ft, \left(4112 \cdot \frac{kip}{ft}\right) \cdot \left(a_{min_{i,j}}\right) \cdot \left(\frac{B_{B_i}}{35 \cdot ft}\right), \left[1349 \cdot kip + \left(110 \cdot \frac{kip}{ft}\right) \cdot \left(a_{min_{i,j}}\right)\right] \cdot \frac{B_{B_i}}{35 \cdot ft}\right]$$

$max(P_{min}) = 11 \cdot kip$

$min(P_{min}) = 11 \cdot kip$

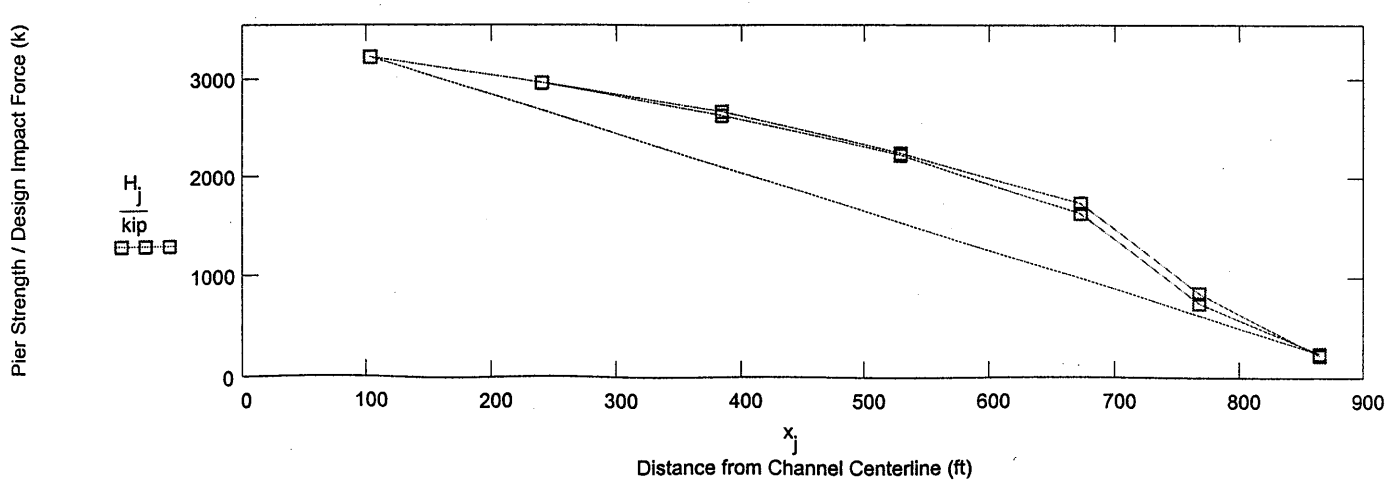
$kN \equiv 1000 \cdot newton$ $\quad knot \equiv 1.689 \cdot \frac{ft}{sec}$ $\quad ton \equiv 2000 \cdot lbf$ $\quad kip \equiv 1000 \cdot lbf$ $\quad tonne \equiv 2205 \cdot lbf$

Method II Analysis Support

Pier No. / Location	x_j ft	B_{P_j} ft	H_j kip	SumAFc$_j$	%Risk$_j$
Row 1 - Pier 1	102	30	3230	0.00000042	1.17
Row 2 - Pier 2	240	40	2960	0.00000188	5.22
Row 3 - Pier 3	384	40	2650	0.00000302	8.38
Row 4 - Pier 4	528	40	2250	0.00000341	9.47
Row 5 - Pier 5	672	40	1650	0.00000330	9.16
Row 6 - Pier 6	768	40	750	0.00000369	10.24
Row 7 - Pier 7	864	40	240	0.00000307	8.53
Row 8 - Pier 8	102	30	3230	0.00000042	1.17
Row 9 - Pier 9	240	40	2960	0.00000188	5.22
Row 10 - Pier 10	384	40	2680	0.00000259	7.19
Row 11 - Pier 11	528	40	2270	0.00000324	9
Row 12 - Pier 12	672	40	1750	0.00000333	9.23
Row 13 - Pier 13	768	40	850	0.00000345	9.57
Row 14 - Pier 14	864	40	230	0.00000232	6.45

TotalAFc = 0.00003604 Total% = 100

ReturnPeriod = 27745 (years)



VESSEL IMPACT RISK ANALYSIS

EXAMPLE BRIDGE on past point # 03 downbound
Consider a total number of 14 brdige piers on both sides of channel.
Use barge group data in the project's final report to describe the vessel configurations in 2050.
Transit velocities of each vessel group are based on Table 6 in the project's final report.

DESIGNER: Liu, Chunhua

NO.:
SHEET: 1 of 13

DATE:18/01/99

Units: feet and tonnes as per 1991 AASHTO Vessel Collision Guide Specification.

DESIGN FOR BARGE & SHIP IMPACT TO SUBSTRUCTURE

Number of Piers   Piers := 14   j := 1.. Piers

Determine the Bridge Characteristics:

Importance Classification (IC) (Section 3.3): Critical Bridge, Acceptable Risk of Bridge Collapse = .0001
(A return period of 1 in 10,000 years)

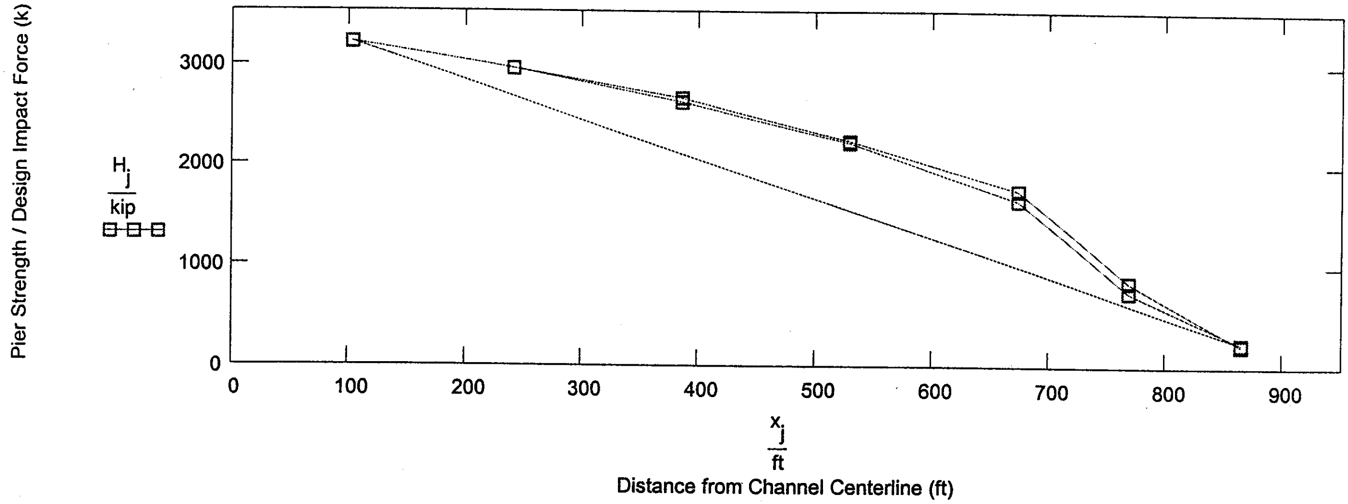
Bp= Bridge pier width, considering angle between channel and bridge centerline.

H = Ultimate horizontal substructure strength.

x = Distance from the centerline of channel to the centerline of the pier.

Note: The subscript " j " refers to the row number of the pier value in the input tables in MathCad. The piers are arranged in the tables corresponding to one side of the channel (double the risk):

Row	Pier	j	$x_j :=$	$BP_j :=$	$H_j :=$
Row 1 -	Pier 1	1	102·ft	30·ft	3230·kip
Row 2 -	Pier 2	2	240·ft	40·ft	2960·kip
Row 3 -	Pier 3	3	384·ft	40·ft	2650·kip
Row 4 -	Pier 4	4	528·ft	40·ft	2250·kip
Row 5 -	Pier 5	5	672·ft	40·ft	1650·kip
Row 6 -	Pier 6	6	768·ft	40·ft	750·kip
Row 7 -	Pier 7	7	864·ft	40·ft	240·kip
Row 8 -	Pier 8	8	102·ft	30·ft	3230·kip
Row 9 -	Pier 9	9	240·ft	40·ft	2960·kip
Row 10 -	Pier 10	10	384·ft	40·ft	2680·kip
Row 11 -	Pier 11	11	528·ft	40·ft	2270·kip
Row 12 -	Pier 12	12	672·ft	40·ft	1750·kip
Row 13 -	Pier 13	13	768·ft	40·ft	850·kip
Row 14 -	Pier 14	14	864·ft	40·ft	230·kip



Determine Navigable Channel Characteristics (Sections 3.4 & 4.2):

j = Pier number

D_w = Water Depth from existing mudline to mean high water (Section 4.2.2).

C = Channel width as shown on Figures 4.2.1-1, 4.2.1-2, and 8.5.1-1. $C := 125 \cdot ft$

θ = Angle of channel turn or bend as shown in Figure 4.8.3.2-1. $\theta := 0 \cdot deg$

region = Waterway region as shown in Figure 4.8.3.2-1
[1 = Straight, 2 = Transition, 3 = Turn/Bend]. $region := 1$

V_c = Waterway current component acting parallel to the vessel transit path. $V_c := 0.6756 \cdot \frac{ft}{sec}$

V_{XC} = Waterway current component acting perpendicular to the vessel transit path. $V_{XC} := 0. \cdot \frac{ft}{sec}$

j	$D_{w_j} :=$
1	12·ft
2	12·ft
3	10·ft
4	10·ft
5	10·ft
6	8·ft
7	8·ft
8	16·ft
9	16·ft
10	13·ft
11	13·ft
12	13·ft
13	10·ft
14	10·ft

Determine Vessel Transit Path (Section 4.2.1):

Vessel transit path as shown in Figure 4.2.1-2 (and Figure 3.7-1 for impact speed distribution).

For this project bridge the centerline of vessel transit path is the same as the centerline of the channel, therefore the distance " x " shown above is the distance from the center of each bridge pier to the centerline of vessel transit path.

x_C = Distance from edge of channel to centerline of vessel transit path.
(Use one-half of the channel width). $x_C := 62.5 \cdot ft$

Determine Vessel Fleet Characteristics Sections (3.5 & 4.4):

Number of different Self Propelled Vessels $SPTypes := 5$ $t := 1 .. SPTypes$

Wp = displacement of tug, ferry, etc

Dp = Draft of tug,ferry, etc

Bp = Width of tug, ferry, etc

Lp = Length of tug, ferry, etc

t	$Wp_t :=$	$Dp_t :=$	$Bp_t :=$	$Lp_t :=$
1	65·ton	4.0·ft	20·ft	50·ft
2	130·ton	7.0·ft	30·ft	100·ft
3	220·ton	9.0·ft	35·ft	120·ft
4	385.13·ton	6.95·ft	23.13·ft	66.76·ft
5	1627.66·ton	6.14·ft	36.82·ft	178.71·ft

Vessel Characteristics and Configuation $Vessels := 6$ $i := 1 .. Vessels$

VT = vessel speed in channel

Db = Draft of barge

Bb = Width of barge

Lb = Length of a single barge

NB = number of barges long (*0 for none*)

Wb = displacement of barge or DWT of ship

SPT = Power Type (defined above, 0 for none)

N_i = number of trips

IVTi = vessel type: 1: ship 0: other

i	$V_{T_i} :=$	$Db_i :=$	$Bb_i :=$	$Lb_i :=$	$NB_i :=$	$Wb_i :=$	SPT_i	$N_i :=$
1	7.4·knot	2.0·ft	47.25·ft	195.10·ft	1	632.17·ton	1	55.774
2	7.4·knot	4.87·ft	69.80·ft	243.62·ft	1	2742.72·ton	2	18.79725
3	7.4·knot	7.33·ft	55.63·ft	197.83·ft	1	2885.72·ton	2	20.6858
4	7.4·knot	10.5·ft	72.10·ft	250.·ft	1	6140.62·ton	3	1.25315
5	10.4·knot	6.95·ft	23.13·ft	66.76·ft	1	385.13·ton	4	50.7614
6	10.4·knot	0·ft	0·ft	0·ft	0	0·ton	5	8.77205

Annual No. of Vessel Transits $\Sigma N = 156.04365$

B_B = vessel width

$$B_{B_i} := \text{if}\left[NB_i > 0, Bb_i, Bp_{(SPT_i)}\right]$$

$$B_B^T = [\, 47.25 \quad 69.8 \quad 55.63 \quad 72.1 \quad 23.13 \quad 36.82 \,]\cdot ft$$

D_{Lt} = power vessel draft

$$D_{Lp_i} := \text{if}\left[SPT_i = 0, 0\cdot ft, Dp_{(SPT_i)}\right]$$

$$D_{Lp}^T = [\, 4 \quad 7 \quad 7 \quad 9 \quad 6.95 \quad 6.14 \,]\cdot ft$$

D_{Lb} = barge draft

$$D_{Lb_i} := \text{if}\left(NB_i = 0, 0\cdot ft, Db_i\right)$$

$$D_{Lb}^T = [\, 2 \quad 4.87 \quad 7.33 \quad 10.5 \quad 6.95 \quad 0 \,]\cdot ft$$

D_{Lv} = vessel draft

$$D_{Lv_i} := \text{if}\left(D_{Lp_i} > D_{Lb_i}, D_{Lp_i}, D_{Lb_i}\right)$$

$$D_{Lv}^T = [\, 4 \quad 7 \quad 7.33 \quad 10.5 \quad 6.95 \quad 6.14 \,]\cdot ft$$

LOA = length overall

$$LOA_i := Lb_i \cdot NB_i + \text{if}\left[SPT_i > 0, Lp_{(SPT_i)}, 0\cdot ft\right]$$

$$LOA^T = [\, 245.1 \quad 343.62 \quad 297.83 \quad 370 \quad 133.52 \quad 178.71 \,]\cdot ft$$

As vessel becomes abberant, tug will separate when tug draft = water depth and the barge group will separate into individual barg

case 1 - barge group intact (tug draft > water depth) case 2 - abberrant barge, use one barge w/o tug (tug draft < water depth)

D_L = Draft of barge or vessel (ft) $\quad D_{L_{i,j}} := \text{if}\left(D_{w_j} > D_{Lv_i}, D_{Lv_i}, \text{if}\left(D_{w_j} > D_{Lb_i}, D_{Lb_i}, 0\cdot ft\right)\right)$

$$D_L = \begin{bmatrix} 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 & 4 \\ 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 & 7 \\ 7.33 & 7.33 & 7.33 & 7.33 & 7.33 & 7.33 & 7.33 & 7.33 & 7.33 & 7.33 & 7.33 & 7.33 & 7.33 & 7.33 \\ 10.5 & 10.5 & 0 & 0 & 0 & 0 & 0 & 10.5 & 10.5 & 10.5 & 10.5 & 10.5 & 0 & 0 \\ 6.95 & 6.95 & 6.95 & 6.95 & 6.95 & 6.95 & 6.95 & 6.95 & 6.95 & 6.95 & 6.95 & 6.95 & 6.95 & 6.95 \\ 6.14 & 6.14 & 6.14 & 6.14 & 6.14 & 6.14 & 6.14 & 6.14 & 6.14 & 6.14 & 6.14 & 6.14 & 6.14 & 6.14 \end{bmatrix} \cdot ft$$

$$D_w^T = \begin{bmatrix} 12 & 12 & 10 & 10 & 10 & 8 & 8 & 16 & 16 & 13 & 13 & 13 & 10 & 10 \end{bmatrix} \cdot ft$$

WLv = vessel displacement assumming only one column of barges will impact the pier $\quad WLv_i := Wb_i \cdot NB_i + \text{if}\left(SPT_i > 0, Wp_{SPT_i}, 0\cdot tonne\right)$

W = displacement of vessel $\quad W_{i,j} := \text{if}\left(D_{w_j} > D_{Lv_i}, WLv_i, \text{if}\left(D_{w_j} > D_{Lb_i}, Wb_i, .001\cdot tonne\right)\right)$

$$W = \begin{bmatrix} 0.632 & 0.632 & 0.632 & 0.632 & 0.632 & 0.632 & 0.632 & 0.632 & 0.632 & 0.632 & 0.632 & 0.632 & 0.632 & 0.632 \\ 2.606 & 2.606 & 2.606 & 2.606 & 2.606 & 2.606 & 2.606 & 2.606 & 2.606 & 2.606 & 2.606 & 2.606 & 2.606 & 2.606 \\ 2.735 & 2.735 & 2.735 & 2.735 & 2.735 & 2.735 & 2.735 & 2.735 & 2.735 & 2.735 & 2.735 & 2.735 & 2.735 & 2.735 \\ 5.769 & 5.769 & 0 & 0 & 0 & 0 & 0 & 5.769 & 5.769 & 5.769 & 5.769 & 5.769 & 0 & 0 \\ 0.699 & 0.699 & 0.699 & 0.699 & 0.699 & 0.699 & 0.699 & 0.699 & 0.699 & 0.699 & 0.699 & 0.699 & 0.699 & 0.699 \\ 1.476 & 1.476 & 1.476 & 1.476 & 1.476 & 1.476 & 1.476 & 1.476 & 1.476 & 1.476 & 1.476 & 1.476 & 1.476 & 1.476 \end{bmatrix} \cdot 10^3 \cdot tonne$$

Determine Design Impact Speed (V) (Section 3.7):

V_{min} = The minimum impact speed, Vmin, at 3xLOA is equal to the yearly mean current of Croatan Sound. $V_{min} := 0.4 \cdot knot$

x_L = Distance equal to 3xLOA from centerline of vessel transit path $x_{L_i} := 3 \cdot LOA_i$

Note: The 3xLOA is computed for each vessel catagory. (The use of a single LOA based on the Method I design vessel, was a simplification included in the AASHTO Guide Spec to reduce the hand computation effort).

$\frac{x_{L_i}}{ft}$
735.3
1030.86
893.49
1110
400.56
536.13

s = transition slope between V_T and V_{min}

$$s_{i,j} := \frac{V_{T_i} - V_{min}}{x_{L_i} - x_C}$$

V = design impact velocity

$$V_{i,j} := \text{if}\left[x_j \le x_C, V_{T_i}, \text{if}\left[x_j \le x_{L_i}, V_{T_i} - (x_j - x_C)\cdot s_{i,j}, V_{min}\right]\right]$$

$$V = \begin{bmatrix} 11.8 & 9.38 & 6.85 & 4.32 & 1.79 & 0.68 & 0.68 & 11.8 & 9.38 & 6.85 & 4.32 & 1.79 & 0.68 & 0.68 \\ 12.02 & 10.33 & 8.57 & 6.82 & 5.06 & 3.88 & 2.71 & 12.02 & 10.33 & 8.57 & 6.82 & 5.06 & 3.88 & 2.71 \\ 11.94 & 9.97 & 7.92 & 5.88 & 3.83 & 2.46 & 1.1 & 11.94 & 9.97 & 7.92 & 5.88 & 3.83 & 2.46 & 1.1 \\ 12.05 & 10.5 & 8.87 & 7.24 & 5.62 & 4.54 & 3.45 & 12.05 & 10.5 & 8.87 & 7.24 & 5.62 & 4.54 & 3.45 \\ 15.59 & 8.7 & 1.5 & 0.68 & 0.68 & 0.68 & 0.68 & 15.59 & 8.7 & 1.5 & 0.68 & 0.68 & 0.68 & 0.68 \\ 16.16 & 11.24 & 6.1 & 0.97 & 0.68 & 0.68 & 0.68 & 16.16 & 11.24 & 6.1 & 0.97 & 0.68 & 0.68 & 0.68 \end{bmatrix} \circ \frac{ft}{sec}$$

Vessel Impact Speeds at each Bridge Pier

Determine Probability of Aberrancy (PA) (Section 4.8.3.2):

BR = Aberrancy base rate (barges):

$$BR_i := \begin{vmatrix} 1.2\cdot 10^{-4} \ \text{if} \ NB_i \ne 0 \quad \text{for barges} \\ 0.6\cdot 10^{-4} \ \text{if} \ NB_i = 0 \quad \text{for ships} \end{vmatrix}$$

R_B = Correction factor for bridge location:

$$R_B := \text{if}\left(region = 1, 1, \text{if}\left(region = 2, 1 + \frac{\theta}{90\cdot deg}, 1 + \frac{\theta}{45\cdot deg}\right)\right) \quad R_B = 1$$

R_C = Correction factor for currents acting parallel to vessel transit path:

$$R_C := 1 + \frac{V_C}{16.89\cdot\frac{ft}{sec}} \quad R_C = 1.04$$

(Note: Eqs for Rc and Rxc were modified to convert from knots to fps)

R_{XC} = Correction factor for crosscurrents acting perpendicular to vessel transit path:

$$R_{XC} := 1 + \frac{V_{XC}}{1.689\cdot\frac{ft}{sec}} \quad R_{XC} = 1$$

R_D = Correction factor for vessel traffic density:

$$R_D := 1$$

PA = Probability of Abberrancy

$$PA_i := BR_i\cdot(R_B)\cdot(R_C)\cdot(R_{XC})\cdot(R_D)$$

$$PA^T = [\,0.0001248 \quad 0.0001248 \quad 0.0001248 \quad 0.0001248 \quad 0.0001248 \quad 0.0000624\,]$$

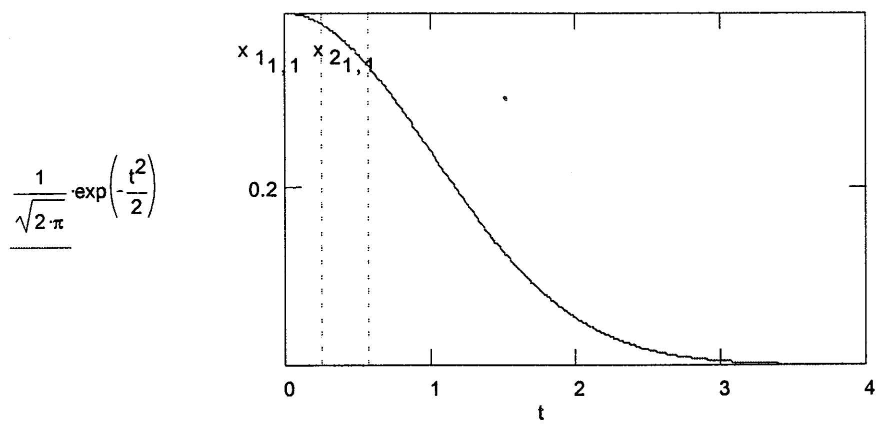
Determine Geometric Probability (PG) (Section 4.8.3.3):

$$x_{1_{i,j}} := \frac{x_j - \frac{B_{P_j} + B_{B_i}}{2}}{\left(LOA_i\right)} \qquad x_{2_{i,j}} := \frac{x_j + \frac{B_{P_j} + B_{B_i}}{2}}{\left(LOA_i\right)}$$

PG = Geometric Probability

$$PG_{i,j} := \mathrm{cnorm}\left(x_{2_{i,j}}\right) - \mathrm{cnorm}\left(x_{1_{i,j}}\right) \qquad t := 0, .01 .. 4$$

$$PG = \begin{bmatrix} 0.115 & 0.088 & 0.042 & 0.014 & 0.003 & 0.001 & 0 & 0.115 & 0.088 & 0.042 & 0.014 & 0.003 & 0.001 & 0 \\ 0.111 & 0.1 & 0.068 & 0.039 & 0.019 & 0.011 & 0.006 & 0.111 & 0.1 & 0.068 & 0.039 & 0.019 & 0.011 & 0.006 \\ 0.108 & 0.092 & 0.056 & 0.027 & 0.01 & 0.005 & 0.002 & 0.108 & 0.092 & 0.056 & 0.027 & 0.01 & 0.005 & 0.002 \\ 0.106 & 0.098 & 0.071 & 0.044 & 0.023 & 0.014 & 0.008 & 0.106 & 0.098 & 0.071 & 0.044 & 0.023 & 0.014 & 0.008 \\ 0.118 & 0.038 & 0.003 & 0 & 0 & 0 & 0 & 0.118 & 0.038 & 0.003 & 0 & 0 & 0 & 0 \\ 0.126 & 0.07 & 0.018 & 0.002 & 0 & 0 & 0 & 0.126 & 0.07 & 0.018 & 0.002 & 0 & 0 & 0 \end{bmatrix}$$



Channel pier impact width location on 'bell curve' for first barge group.

Determine Vessel Collision Energy (KE) (Section 3.8):

UK = Underkeel clearance

$$UK_{c_{i,j}} := \mathrm{if}\left(D_{L_{i,j}} > 0\cdot ft, D_{w_j} - D_{L_{i,j}}, 0\cdot ft\right)$$

C_H = Hydrodynamic mass coefficient:

$$C_{H_{i,j}} := \mathrm{if}\left(UK_{c_{i,j}} \ge 0.5\cdot D_{L_{i,j}}, 1.05, \mathrm{if}\left(UK_{c_{i,j}} \le 0.10\cdot D_{L_{i,j}}, 1.25, 1.05 + \frac{.5\cdot D_{L_{i,j}} - UK_{c_{i,j}}}{.5\cdot D_{L_{i,j}} - .1\cdot D_{L_{i,j}}}\cdot .2\right)\right)$$

KE = Vessel Collision Energy

$$KE_{i,j} := \frac{C_{H_{i,j}}\cdot W_{i,j}\cdot \left(V_{i,j}\right)^2}{2\cdot g}$$

$$C_H = \begin{bmatrix} 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 \\ 1.05 & 1.05 & 1.086 & 1.086 & 1.086 & 1.229 & 1.229 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.086 & 1.086 \\ 1.05 & 1.05 & 1.118 & 1.118 & 1.118 & 1.25 & 1.25 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.118 & 1.118 \\ 1.229 & 1.229 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.181 & 1.181 & 1.181 & 1.05 & 1.05 \\ 1.05 & 1.05 & 1.081 & 1.081 & 1.081 & 1.224 & 1.224 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.081 & 1.081 \\ 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.149 & 1.149 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 & 1.05 \end{bmatrix}$$

$$KE = \begin{bmatrix} 3170 & 2002 & 1067 & 424 & 73 & 10 & 10 & 3170 & 2002 & 1067 & 424 & 73 & 10 & 10 \\ 13537 & 10007 & 7125 & 4503 & 2479 & 1656 & 807 & 13537 & 10007 & 6891 & 4354 & 2398 & 1463 & 713 \\ 14023 & 9789 & 6580 & 3617 & 1534 & 710 & 141 & 14023 & 9789 & 6180 & 3398 & 1441 & 635 & 126 \\ 35283 & 26753 & 0 & 0 & 0 & 0 & 0 & 30155 & 22865 & 18368 & 12253 & 7372 & 0 & 0 \\ 6111 & 1902 & 58 & 12 & 12 & 13 & 13 & 6111 & 1902 & 57 & 11 & 11 & 12 & 12 \\ 13867 & 6706 & 1977 & 50 & 24 & 27 & 27 & 13867 & 6706 & 1977 & 50 & 24 & 24 & 24 \end{bmatrix} \circ kip \cdot ft$$

Determine Ship Collision Force on Pier (P_B) (Section 3.9):

The Ship collision force on the piers (P_S) (Section

DWT = Deadweight tonnage of ship

$$DWT_i := \text{if}\left[NB_i = 0, Wp_{(SPT_i)}, 0 \cdot tonne\right]$$

P_S = Ship Collision Force

$$P_{S_{i,j}} := (220) \cdot \sqrt{\frac{DWT_i}{tonne}} \cdot \left(\frac{V_{i,j}}{27}\right) \cdot \left(\frac{sec \cdot kip}{ft}\right) \qquad \max(P_S) = 5058.38871972 \circ kip$$

Determine Barge Collision Force on Pier (P_B) (Section 3.12):

Determine the Barge Bow Damage Depth a_B (Section 3.13):

a_B = Barge Bow Damage Depth

$$a_{B_{i,j}} := \left[\sqrt{\left[1 + \frac{KE_{i,j}}{(5672 \cdot (kip \cdot ft))}\right]} - 1\right] \cdot \left[\frac{10.2 \cdot ft}{\left(\frac{B_{B_i}}{35 \cdot ft}\right)}\right]$$

The barge collision force on the piers (P_B)

P_B = Barge or ship Collision Force

$$P_{B_{i,j}} := \text{if}\left[a_{B_{i,j}} < 0.34 \cdot ft, \left(4112 \cdot \frac{kip}{ft}\right) \cdot \left(a_{B_{i,j}}\right) \cdot \left(\frac{B_{B_i}}{35 \cdot ft}\right), \left[1349 \cdot (kip) + \left(110 \cdot \frac{kip}{ft}\right) \cdot \left(a_{B_{i,j}}\right)\right] \cdot \frac{B_{B_i}}{35 \cdot ft}\right]$$

$$P_B = \begin{bmatrix} 2100 & 2004 & 1922 & 1541 & 268 & 38 & 38 & 2100 & 2004 & 1922 & 1541 & 268 & 38 & 38 \\ 3633 & 3434 & 3254 & 3071 & 2913 & 2844 & 2767 & 3633 & 3434 & 3238 & 3060 & 2907 & 2827 & 2560 \\ 3113 & 2875 & 2671 & 2458 & 2287 & 2212 & 516 & 3113 & 2875 & 2644 & 2441 & 2279 & 2205 & 462 \\ 4672 & 4340 & 0 & 0 & 0 & 0 & 0 & 4477 & 4174 & 3967 & 3652 & 3358 & 0 & 0 \\ 1387 & 1066 & 216 & 44 & 44 & 49 & 49 & 1387 & 1066 & 209 & 42 & 42 & 44 & 44 \\ 2380 & 1955 & 1600 & 183 & 90 & 98 & 98 & 2380 & 1955 & 1600 & 183 & 90 & 90 & 90 \end{bmatrix} \circ kip$$

Use Ship Collision Force if Number of Barges = 0, otherwise use Barge Collision Force

$$P_{i,j} := \text{if}\left(NB_i = 0, P\,S_{i,j}, P\,B_{i,j}\right)$$

Determine Probability of Collapse (PC) (Section 4.8.3.4):

case 1 : For $0.0 \le \frac{H}{P}$ and $\frac{H}{P} \le 0.1$ $\qquad PC1_{i,j} := 0.1 + 9 \cdot \left(.1 - \frac{H_j}{P_{i,j}}\right)$

case 2: For $0.1 \le \frac{H}{P}$ and $\frac{H}{P} \le 1.0$ $\qquad PC2_{i,j} := \frac{\left(1 - \frac{H_j}{P_{i,j}}\right)}{9}$

case3: For $\frac{H}{P} \ge 1.0$ $\qquad PC3_{i,j} := 1 \cdot 10^{-99}$

PC = Probability of Collapse

$$PC_{i,j} := \text{if}\left(\frac{H_j}{P_{i,j}} < 0.1, PC1_{i,j}, \text{if}\left(\frac{H_j}{P_{i,j}} < 1.0, PC2_{i,j}, PC3_{i,j}\right)\right)$$

$$PC = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.012 & 0.015 & 0.021 & 0.03 & 0.048 & 0.082 & 0.22 & 0.012 & 0.015 & 0.019 & 0.029 & 0.044 & 0.078 & 0.191 \\ 0 & 0 & 0.001 & 0.009 & 0.031 & 0.073 & 0.059 & 0 & 0 & 0 & 0.008 & 0.026 & 0.068 & 0.056 \\ 0.034 & 0.035 & 0 & 0 & 0 & 0 & 0 & 0.031 & 0.032 & 0.036 & 0.042 & 0.053 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.04 & 0.018 & 0 & 0 & 0 & 0 & 0 & 0.04 & 0.018 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Determine the Calculated Annual Frequency of Collapse (AFc) (Section 4.8.3):

PS = PROBABILITY OF SCOUR

$$PS := 1$$

AFc = Annual Frequency of Collapse per vessel per pier

$$AFc_{i,j} := (N_i)\cdot(PA_i)\cdot(PG_{i,j})\cdot(PC_{i,j})\cdot(PS)$$

SumAFc = Annual Frequency of Collapse per pier

$$SumAFc_j := \sum_{i=1}^{Vessels} AFc_{i,j}$$

Total = Annual Frequency of Collapse

$$TotalAFc := \sum_{j=1}^{Piers} SumAFc_j$$

ReturnPeriod = number of years between collapse events

$$ReturnPeriod := \frac{1}{\displaystyle\sum_{j=1}^{Piers} SumAFc_j}$$

The total bridge return period for these 13 piers (in years) is:

$$ReturnPeriod = 18588$$

Pier No.	$SumAFc_j$
1	0.00000654
2	0.0000048
3	0.00000343
4	0.0000034
5	0.00000297
6	0.00000294
7	0.00000315
8	0.00000648
9	0.00000475
10	0.00000347
11	0.00000348
12	0.00000285
13	0.00000278
14	0.00000276

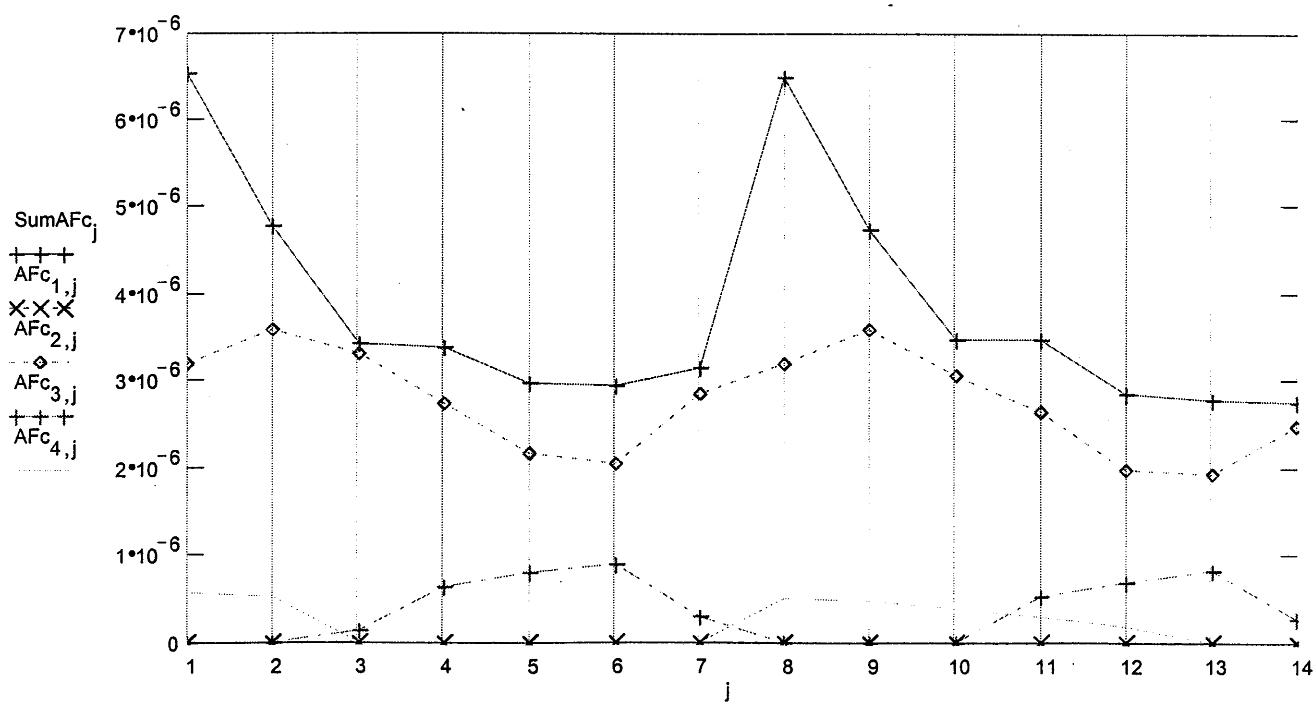
%Risk = percentage of the total risk for each pier

$$\%Risk_j := \frac{SumAFc_j}{TotalAFc}\cdot 100$$

Total% = total risk percentage (should equal 100 percent)

$$Total\% := \sum_{j=1}^{Piers} \%Risk_j \qquad Total\% = 100$$

$$TotalAFc = 0.0000538$$



DESIGN SUMMARY

Barge and Pier Data

$\frac{LOA_i}{ft}$	N_i
245.1	55.774
343.62	18.7972
297.83	20.6858
370	1.2532
133.52	50.7614
178.71	8.7721

$\frac{H_j}{kip}$	$\frac{D_{w_j}}{ft}$	$\frac{x_j}{ft}$	$\frac{B_{P_j}}{ft}$
3230	12	102	30
2960	12	240	40
2650	10	384	40
2250	10	528	40
1650	10	672	40
750	8	768	40
240	8	864	40
3230	16	102	30
2960	16	240	40
2680	13	384	40
2270	13	528	40
1750	13	672	40
850	10	768	40
230	10	864	40

W = barge + Tug + cargo
LOA= length of vessel
N= number of one way passages the barge makes in a year
H= pier ultimate strength
Dw= water depth
x= distance center line channel to center line pier
Bp= pier width
V= velocity of the barge at this pier
PG= geometric probability that this pier may be 'hit'
KE= kinetic energy of vessel and hydrodynamic mass
aB= depth of damage to barge
PB= force from an impact with this pier
PC=probability of collapse if hit
AF= probability of collapse taking all factors into account.

Geometric & Probability Variables

$$V = \begin{bmatrix} 11.8 & 9.38 & 6.85 & 4.32 & 1.79 & 0.68 & 0.68 & 11.8 & 9.38 & 6.85 & 4.32 & 1.79 & 0.68 & 0.68 \\ 12.02 & 10.33 & 8.57 & 6.82 & 5.06 & 3.88 & 2.71 & 12.02 & 10.33 & 8.57 & 6.82 & 5.06 & 3.88 & 2.71 \\ 11.94 & 9.97 & 7.92 & 5.88 & 3.83 & 2.46 & 1.1 & 11.94 & 9.97 & 7.92 & 5.88 & 3.83 & 2.46 & 1.1 \\ 12.05 & 10.5 & 8.87 & 7.24 & 5.62 & 4.54 & 3.45 & 12.05 & 10.5 & 8.87 & 7.24 & 5.62 & 4.54 & 3.45 \\ 15.59 & 8.7 & 1.5 & 0.68 & 0.68 & 0.68 & 0.68 & 15.59 & 8.7 & 1.5 & 0.68 & 0.68 & 0.68 & 0.68 \\ 16.16 & 11.24 & 6.1 & 0.97 & 0.68 & 0.68 & 0.68 & 16.16 & 11.24 & 6.1 & 0.97 & 0.68 & 0.68 & 0.68 \end{bmatrix} \cdot \frac{ft}{sec}$$

$$a_B = \begin{bmatrix} 1.88 & 1.23 & 0.68 & 0.28 & 0.05 & 0.01 & 0.01 & 1.88 & 1.23 & 0.68 & 0.28 & 0.05 & 0.01 & 0.01 \\ 4.3 & 3.39 & 2.57 & 1.74 & 1.02 & 0.7 & 0.35 & 4.3 & 3.39 & 2.5 & 1.69 & 0.99 & 0.62 & 0.31 \\ 5.54 & 4.18 & 3.01 & 1.8 & 0.82 & 0.39 & 0.08 & 5.54 & 4.18 & 2.86 & 1.7 & 0.77 & 0.35 & 0.07 \\ 8.35 & 6.89 & 0 & 0 & 0 & 0 & 0 & 7.49 & 6.15 & 5.24 & 3.85 & 2.56 & 0 & 0 \\ 6.81 & 2.4 & 0.08 & 0.02 & 0.02 & 0.02 & 0.02 & 6.81 & 2.4 & 0.08 & 0.02 & 0.02 & 0.02 & 0.02 \\ 8.3 & 4.63 & 1.56 & 0.04 & 0.02 & 0.02 & 0.02 & 8.3 & 4.63 & 1.56 & 0.04 & 0.02 & 0.02 & 0.02 \end{bmatrix} \cdot ft$$

$$KE = \begin{bmatrix} 3170 & 2002 & 1067 & 424 & 73 & 10 & 10 & 3170 & 2002 & 1067 & 424 & 73 & 10 & 10 \\ 13537 & 10007 & 7125 & 4503 & 2479 & 1656 & 807 & 13537 & 10007 & 6891 & 4354 & 2398 & 1463 & 713 \\ 14023 & 9789 & 6580 & 3617 & 1534 & 710 & 141 & 14023 & 9789 & 6180 & 3398 & 1441 & 635 & 126 \\ 35283 & 26753 & 0 & 0 & 0 & 0 & 0 & 30155 & 22865 & 18368 & 12253 & 7372 & 0 & 0 \\ 6111 & 1902 & 58 & 12 & 12 & 13 & 13 & 6111 & 1902 & 57 & 11 & 11 & 12 & 12 \\ 13867 & 6706 & 1977 & 50 & 24 & 27 & 27 & 13867 & 6706 & 1977 & 50 & 24 & 24 & 24 \end{bmatrix} \circ kip \cdot ft$$

$$PG = \begin{bmatrix} 0.115 & 0.088 & 0.042 & 0.014 & 0.003 & 0.001 & 0 & 0.115 & 0.088 & 0.042 & 0.014 & 0.003 & 0.001 & 0 \\ 0.111 & 0.1 & 0.068 & 0.039 & 0.019 & 0.011 & 0.006 & 0.111 & 0.1 & 0.068 & 0.039 & 0.019 & 0.011 & 0.006 \\ 0.108 & 0.092 & 0.056 & 0.027 & 0.01 & 0.005 & 0.002 & 0.108 & 0.092 & 0.056 & 0.027 & 0.01 & 0.005 & 0.002 \\ 0.106 & 0.098 & 0.071 & 0.044 & 0.023 & 0.014 & 0.008 & 0.106 & 0.098 & 0.071 & 0.044 & 0.023 & 0.014 & 0.008 \\ 0.118 & 0.038 & 0.003 & 0 & 0 & 0 & 0 & 0.118 & 0.038 & 0.003 & 0 & 0 & 0 & 0 \\ 0.126 & 0.07 & 0.018 & 0.002 & 0 & 0 & 0 & 0.126 & 0.07 & 0.018 & 0.002 & 0 & 0 & 0 \end{bmatrix}$$

$$PC = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.012 & 0.015 & 0.021 & 0.03 & 0.048 & 0.082 & 0.22 & 0.012 & 0.015 & 0.019 & 0.029 & 0.044 & 0.078 & 0.191 \\ 0 & 0 & 0.001 & 0.009 & 0.031 & 0.073 & 0.059 & 0 & 0 & 0 & 0.008 & 0.026 & 0.068 & 0.056 \\ 0.034 & 0.035 & 0 & 0 & 0 & 0 & 0 & 0.031 & 0.032 & 0.036 & 0.042 & 0.053 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.04 & 0.018 & 0 & 0 & 0 & 0 & 0 & 0.04 & 0.018 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$P_B = \begin{bmatrix} 2100 & 2004 & 1922 & 1541 & 268 & 38 & 38 & 2100 & 2004 & 1922 & 1541 & 268 & 38 & 38 \\ 3633 & 3434 & 3254 & 3071 & 2913 & 2844 & 2767 & 3633 & 3434 & 3238 & 3060 & 2907 & 2827 & 2560 \\ 3113 & 2875 & 2671 & 2458 & 2287 & 2212 & 516 & 3113 & 2875 & 2644 & 2441 & 2279 & 2205 & 462 \\ 4672 & 4340 & 0 & 0 & 0 & 0 & 0 & 4477 & 4174 & 3967 & 3652 & 3358 & 0 & 0 \\ 1387 & 1066 & 216 & 44 & 44 & 49 & 49 & 1387 & 1066 & 209 & 42 & 42 & 44 & 44 \\ 2380 & 1955 & 1600 & 183 & 90 & 98 & 98 & 2380 & 1955 & 1600 & 183 & 90 & 90 & 90 \end{bmatrix} \circ kip$$

Determine MINIMUM Barge Collision Force on Pier (P_B) (Section 3.12):

$D_{w_i} := 10 \cdot ft$	Design water depth	
$d_{L_i} := 2 \cdot ft$	The empty barge draft	
$w_i := 181.4 \cdot tonne$	An empty 35x195 foot hopper barge displacement	$200 \cdot ton = 181.4 \circ tonne$
$V_{min} := 0.4 \cdot knot$	The drifting barge impact speed = annual mean current	$1 \cdot knot = 1.689 \circ \frac{ft}{sec}$

First, Determine Barge Collision Energy (KE) (Section 3.8):

UK = Underkeel clearance: $UK_{c_{i,j}} := D_{w_i} - d_{L_i}$

CH = Hydrodynamic mass coefficient:

$$C_{H_{i,j}} := \text{if}\left(UK_{c_{i,j}} \geq 0.5 \cdot d_{L_i}, 1.05, \text{if}\left(UK_{c_{i,j}} \leq 0.10 \cdot d_{L_i}, 1.25, 1.05 + \frac{.5 \cdot d_{L_i} - UK_{c_{i,j}}}{.5 \cdot d_{L_i} - .1 \cdot d_{L_i}} \cdot .2\right)\right)$$

KE_{min} = Barge MIN Collision Energy

$$KE_{min_{i,j}} := \frac{C_{H_{i,j}} \cdot w_i \cdot (V_{min})^2}{2 \cdot g}$$

$\max(KE_{min}) = 3 \cdot ft \cdot kip$

$\min(KE_{min}) = 3 \cdot ft \cdot kip$

Second, Determine the MINIMUM Barge Bow Damage Depth a_B (Section 3.13):

$$a_{min_{i,j}} := \left[\sqrt{1 + \frac{KE_{min_{i,j}}}{5672 \cdot (kip \cdot ft)}} - 1\right] \cdot \left[\frac{10.2 \cdot ft}{\left(\frac{B_{B_i}}{35 \cdot ft}\right)}\right]$$

$\max(a_{min}) = 0.0041 \cdot ft$

$\min(a_{min}) = 0.0013 \cdot ft$

The MINIMUM barge collision force on the pier (P_B) is then:

$$P_{min_{i,j}} := \text{if}\left[a_{min_{i,j}} < 0.34 \cdot ft, \left(4112 \cdot \frac{kip}{ft}\right) \cdot \left(a_{min_{i,j}}\right) \cdot \left(\frac{B_{B_i}}{35 \cdot ft}\right), \left[1349 \cdot kip + \left(110 \cdot \frac{kip}{ft}\right) \cdot \left(a_{min_{i,j}}\right)\right] \cdot \frac{B_{B_i}}{35 \cdot ft}\right]$$

$\max(P_{min}) = 11 \circ kip$

$\min(P_{min}) = 11 \circ kip$

$kN \equiv 1000 \cdot newton$ $\quad knot \equiv 1.689 \cdot \frac{ft}{sec}$ $\quad ton \equiv 2000 \cdot lbf$ $\quad kip \equiv 1000 \cdot lbf$ $\quad tonne \equiv 2205 \cdot lbf$

Method II Analysis Summary

Pier No. / Location	N_i	x_j (ft)	$B\,P_j$ (ft)	H_j (kip)	$SumAFc_j$	$\%Risk_j$
Row 1 - Pier 1	55.77	102	30	3230	0.00000654	12.15
Row 2 - Pier 2	18.8	240	40	2960	0.00000480	8.92
Row 3 - Pier 3	20.69	384	40	2650	0.00000343	6.38
Row 4 - Pier 4	1.25	528	40	2250	0.00000340	6.31
Row 5 - Pier 5	50.76	672	40	1650	0.00000297	5.52
Row 6 - Pier 6	8.77	768	40	750	0.00000294	5.47
Row 7 - Pier 7		864	40	240	0.00000315	5.85
Row 8 - Pier 8		102	30	3230	0.00000648	12.05
Row 9 - Pier 9		240	40	2960	0.00000475	8.84
Row 10 - Pier 10		384	40	2680	0.00000347	6.45
Row 11 - Pier 11		528	40	2270	0.00000348	6.46
Row 12 - Pier 12		672	40	1750	0.00000285	5.3
Row 13 - Pier 13		768	40	850	0.00000278	5.16
Row 14 - Pier 14		864	40	230	0.00000276	5.14

TotalAFc = 0.00005380   Total% = 100

ReturnPeriod = 18588   (years)