BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

# 01481 LIONS GATE BRIDGE

## VESSEL COLLISION RISK ASSESSMENT & MITIGATION

## FINAL REPORT

MARCH 16, 2018

MMM GROUP

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BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

## FINAL REPORT

PROJECT NO.: 13M-00273-02
DATE: MARCH 2018

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March 16, 2018

FINAL REPORT

Willem Jellema, P.Eng., C.Eng.
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Suite 310 - 1500 Woolridge Street
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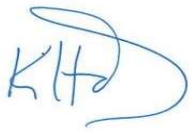
Dear Wim,

Subject: **01481 Lions Gate Bridge Vessel Collision Risk Assessment & Mitigation Report**

I am pleased to be sending our vessel collision risk assessment and mitigation final report for the 01481 Lions Gate Bridge. The report's contents document our comprehensive risk review and development of mitigation concepts in clear language, with supporting tables and graphics.

Many thanks to the Ministry team for the delivery and technical insight on this challenging project.

Yours sincerely,



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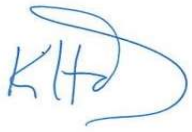

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# EXECUTIVE SUMMARY

The British Columbia Ministry of Transportation and Infrastructure (the Ministry) has completed an assessment of the risk for marine vessel contact with the 01481 Lions Gate Bridge (LGB) at First Narrows and the 01459 Ironworkers Memorial Bridge (IWMB) at Second Narrows in Vancouver's Burrard Inlet Harbour. This report provides a summary of a detailed probabilistic risk analysis and physical mitigation concepts for the LGB.

Opened in 1938, the LGB is an 846m long suspension bridge spanning the First Narrows of the Burrard Inlet with a 472m main span supported by two main towers. The South Tower is within the water and the North Tower is on land set back from the shoreline by several metres at all tide levels. The main towers are constructed of steel, each supported on reinforced concrete pedestals and foundation. The bridge carries three lanes of vehicular traffic and two multi-use paths for pedestrians and cyclists between Vancouver and the north shore municipalities of West Vancouver and North Vancouver. A 1984 report **(1)** identified the North Tower as exposed to vessel impact and a 1986 report **(2)** identified the South Tower pedestal and legs as exposed to vessel impact. To mitigate the vessel collision risks, in 1988, a rock berm was installed around the North Tower and a protection collar was installed at the base of the South Tower in 1988. At the time, the potential risk to the steel tower legs was identified for future study but was considered minor since contact was only from vessels with a flared bow shape that constituted a small and maneuverable portion of the total vessel traffic at that time. A 1997 study **(3)** revisited the vessel collision risk to the bridge and quantified the risks to be lower than the Code-required threshold. There have been no commercial vessel collisions with the LGB since it was constructed.

The vessel collision risk assessment completed for this study was conducted in accordance with the requirements and procedures for new bridges in the Canadian Highway Bridge Design Code (the Code) **(4)**, supplemented by the American Association of State Highway and Transportation Officials Standards **(5) (6)**. Based on the Code, highway bridges crossing navigable waterways are classified as one of the following:

- **Class I** bridges are of critical importance, including those that must remain open to all traffic after a vessel collision. The maximum annual frequency of collapse for the whole bridge shall be 0.0001, which is a return period of 1 in 10,000 years.
- **Class II** bridges are of regular importance, including those that must remain open to emergency and security vehicles after a vessel collision. The maximum annual frequency of collapse for the whole bridge shall be 0.001, which is a return period of 1 in 1,000 years.

The vessel collision risk analysis was conducted based on site specific data related to the First Narrows waterway characteristics, vessel fleet characteristics, and existing bridge characteristics. This data was obtained from publicly available sources as referenced in this report. The information in the public domain was also validated through discussions with the Vancouver Fraser Port Authority (VFPA) and the Pacific Pilotage Authority (PPA).

The risk analysis evaluated the present-day mandatory vessel operating requirements, the characteristics of the navigation channel and approaches to the channel, the vessel fleet and the structural configuration and capacity of the LGB. The annual number of ship transits for the current vessel fleet passing under the LGB was estimated to be 4,534 trips per year (excluding tugs, small barges, booms, small craft and recreational vessels). The risk analysis was then expanded to reflect the expected vessel traffic 25 years from today. For this 25-year projection, growth rates were based on known expansion projects or forecasted annual increases in the number of transits for each vessel class. The 25-year projection for the future vessel fleet transits was estimated to be 6,337 trips per year.

The base case analyses used the Code's base rate for vessel aberrancy (the rate at which vessels navigating through a channel are likely to go off course). The base rate was adjusted to reflect site-specific vessel operating practices in First Narrows in accordance with existing Traffic Control Zone requirements by the VFPA. Adjustments to the aberrancy base rate depended on the size, type and loading condition of the transiting vessels and considered the number of pilots, vessel maneuverability, tug escort, water currents, traffic density, daylight / visibility restrictions, electronic navigation tools and port state control. The magnitude of each adjustment was established based on Code recommendations, published research, and previous risk studies that have been accepted by federal agencies as appropriate for similar marine risk analyses. The variability in each of the adjustment factors was captured through sensitivity analyses.

The factors used in the study reflect the best estimate of the reality of the bridge site, waterway and fleet characteristics. Sensitivity runs were completed to gauge the significance of uncertainties for key input variables including (b) probability of vessel aberrancy accident base rate; (c) South Tower water depth; and (d) planning horizon for the bridge. Water levels and depths at the bridge towers were adjusted in the risk analysis to adjust for predicted sea level rise and potential ride-up of vessels starting to run aground near the towers.

Results of the base case risk analyses are summarized as follows:

| BASE CASE | ANNUAL FREQUENCY OF COLLAPSE (AFC) FOR TOTAL BRIDGE Return Period (Years) | | | | |
|---|---|---|---|---|---|
| | Base Case Risk Analysis Results | | | Code-Based Risk Threshold (7) | |
| | Inbound Vessels | Outbound Vessels | Total | Class I *Critical Importance* | Class II *Regular Importance* |
| **Present Day Vessel Traffic** | 29,146 | 6,383 | **5,236** | 10,000 | 1,000 |
| **Future Vessel Traffic (25 Years)** | 22,770 | 4,986 | **4,091** | 10,000 | 1,000 |

These results indicate that the AFC meets the criteria for a Class II (Regular Importance) highway bridge but does not meet the criteria for a Class I (Critical Importance) highway bridge. Key findings from the study were:

1. The primary bridge vulnerability is the potential impact of the flared bow of a container, general cargo or cruise ships with the South Tower steel legs at elevations significantly above the water. The overhang of the flared bow could contact the tower leg at a relatively weak structural location high above the water before the portion of the ship's bulbous bow below the water contacts the robust concrete pedestal / foundation.
2. The potential vulnerability of the concrete pedestal / foundation is low since the resistance strength of these bridge components is very high. Therefore, the risk of collapse resulting from tankers and bulk carrier impacts (which have blunt bows and contact the South Tower concrete protection collar on the foundation at or below the waterline) is not significant.
3. Over 80% of the collision risks to the bridge are due to outbound vessels. This is because of the South Tower's location inside the inbound turn in the channel and its partial protection inside a small cove with shallow water depths.
4. Reducing the water depth at the South Tower from the existing El -7.0m to a revised elevation of El -4.0m (or less) would result in return periods exceeding 10,000 years. This change in risk is related to the larger container, general cargo, and cruise ships, which start to run aground at these depths.

In developing physical protection concepts, key site-specific issues were considered:

1. **Hydraulics:** There is a relatively large, 5m daily tidal range. Peak currents are up to 5 knots and generally uniform across the narrows in a direction roughly parallel to the vessel transit paths. The tidal range and local currents present significant construction challenges. In addition, a new protection structure may alter the currents through First Narrows with potential impacts to vessel traffic.
2. **Port and Vessel Operations:** The South Tower is located 135m from the edge of the navigation channel, providing sufficient room for a protection structure. The area directly adjacent to the South Tower is more commonly used by small fishing / recreational vessels and log booms. Construction and permanent works must consider these users in terms of visibility, communication and component detailing.
3. **Environmental Impacts:** The seafloor around the South Tower is valued marine habitat and suitable mitigation for any habitat loss and / or construction activities will need to be developed.
4. **Public / Historic Context:** The Bridge is recognized as a National Historic Site of Canada and the South Tower is a prominent feature observed from close range by the popular Stanley Park Seawall. Construction and permanent works will need to be cognizant of this context in terms of visibility, communication and component detailing.
5. **Geotechnical:** The exposed or shallow sandstone around the South Tower is of suitable capacity to support a structure. However, the rock is characterized as weak and can be excavated easily. Depending on the layout and type of a protective structure, settlement impacts to the existing South Tower may require further consideration at detailed design.
6. **Bathymetry:** The seafloor is very shallow (i.e. exposed at low tide) behind the South Tower (towards the park) and is steeply inclined, achieving a depth of over 10m in front of the South Tower.

Physical protection options were developed and two rock fill options were identified for further concept development: the (3a) **Rock Fill Protection Berm** and (3e) **Combi-Wall**. Both options provide vessel collision resistance primarily through a rock fill load path to the underlying rock. While the berm option is comprised solely of rock fill material, the combi-wall introduces structural retaining components to reduce the volume of fill by about 35% and the sea floor footprint by about 50%. Both concepts provide protection for all vessel types currently transiting First Narrows.

The rock fill berm option is conceptually simple in that an aberrant vessel effectively runs aground on the front slope of the rock fill berm before reaching the South Tower. The combi-wall concept is a retaining structure comprised of closely-spaced steel “king piles” with lighter steel sheet piles serving as infill between the king piles. For a vessel collision, the main wall serves as a vertical barrier that pushes in and engages the passive capacity of the retained rock fill.

The rock fill berm option is the preferred concept based on several key project criteria and has an estimated capital cost of **$15M**.

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# 1 INTRODUCTION

## 1.1 PROJECT BACKGROUND AND REPORT OUTLINE

The British Columbia Ministry of Transportation and Infrastructure (the Ministry) is undertaking a review and risk assessment of vessel impact issues for the 01481 Lions Gate Bridge (LGB) at First Narrows and the 01459 Iron Workers Memorial Bridge (IWMB) at Second Narrows in Vancouver's Burrard Inlet Harbour. This report provides a summary of a detailed probabilistic risk analysis and proposed physical mitigation concepts for the LGB.

MMM Group Limited (MMM) was retained by the Ministry to perform the vessel collision studies for the bridge. MMM assembled a team of experts representing a diverse and in-depth level of specialty experience assessing the risk and consequence of vessel impact on bridges. Acting as sub-consultants to MMM, the team included: Michael Knott, PE (Moffatt & Nichol) – risk assessment; Norman Allyn, P.Eng. – vessel grounding analysis; Stan Cowdell, P.Eng. (Westmar Project Advisors) – marine structures and local practices; Edwin Wang and Des Goold (Northwest Hydraulics Consultants) - hydrotechnical analysis; Chris Anderson - Master Mariner; and Wayne Saunders – marine construction and cost specialist. The MMM team has met with the Ministry, Vancouver Fraser Port Authority (VFPA) and Pacific Pilotage Authority (PPA) on several occasions as part of this work.

- **Section 1** introduces the project and provides background information on the bridge and the topic of vessel collision.
- **Sections 2, 3 and 4** provide detailed information relating to the waterway, bridge site and vessel fleet, respectively.
- **Section 5** provides a summary of vessel grounding behaviour including both vessel ride-up and ploughing.
- **Section 6 and 7** provide a description of the risk evaluation and results, respectively.
- **Section 8** provides an overview of typical physical mitigation concepts and site constraints.
- **Section 9** provides a summary of physical mitigation concepts and review of various site factors.
- **Section 10** provides a summary of report findings.

The current vessel collision risk assessment was conducted in accordance with the requirements and procedures of the 2014 Canadian Highway Bridge Design Code (the Code) **(4)**, supplemented by the American Association of State Highway and Transportation Officials Standards **(5) (6)**. The analysis used site specific data related to the Second Narrows waterway characteristics, vessel fleet characteristics, existing bridge characteristics and the mandatory vessel navigations practices specified by the VFPA. Data for the analysis was obtained from publicly available sources as referenced in this report. The information in the public domain was also validated through discussions with the VFPA and the PPA.

This report only considers physical protection risk mitigation measures. Under the jurisdiction of the VFPA, there is an extensive set of operating procedures currently in place at First Narrows. The project's risk analysis has considered these operational procedures in quantifying the vessel collision risks.

## 1.2 LGB, PREVIOUS STUDIES AND RELEVANT INFORMATION

Opened in 1938, the Lions Gate Bridge is an 846m long suspension bridge spanning the First Narrows of the Burrard Inlet with a 472m main span supported by two main towers (**Figure 1-1**). The main towers are

constructed of steel, each supported on reinforced concrete pedestals and foundation. The bridge carries three lanes of vehicular traffic and two multi-use paths for pedestrians and cyclists between Vancouver and the north shore municipalities of West Vancouver and North Vancouver (**Figure 1-2**).

A report by the Canadian Coast Guard in 1982 identified that the Lions Gate Bridge was at risk to ship collision due to the large volume of vessels transiting First Narrows **(8)**. Subsequently, reports were completed by Buckland & Taylor Ltd. (B&T) to investigate the risk of ship collision with the North and South Towers of Lions Gate Bridge in 1984 **(1)** and 1986 **(2)** , respectively, as well as the overall bridge in 1997 **(3)**.

The 1984 report **(1)** was conducted for the North Tower and determined that the pedestal was not capable of resisting significant ship impact and would likely overturn causing catastrophic collapse of the structure. At high tide, small vessels could reach the pedestals and larger vessels could run up the beach and strike the pedestals. In 1988, a rock berm was installed at the North Tower to mitigate the risk to an acceptable level.

The 1986 report **(2)** was conducted for the South Tower and summarized the vulnerability of the tower pedestals to impact from an aberrant vessel. The original pedestals and caissons are constructed of unreinforced concrete and were found to have insufficient capacity to resist vessel impacts. The steel tower legs, above the pedestals, were found to have minimal capacity to vessel impact but were only exposed to impact from vessels with a flared bow shape. The report noted that such vessels included cruise ships, naval ships, and ice breakers, but that they constituted a small portion of the total traffic and were highly maneuverable vessels in comparison to typical freighters. As such, the report focused largely on the higher-volume freighter traffic that was more likely to strike the pedestals. In 1988, a protection collar was installed at the base of the South Tower to protect the pedestals from vessel impact (**Figure 1-3**).

**Figure 1-1: Lions Gate Bridge, Looking East**

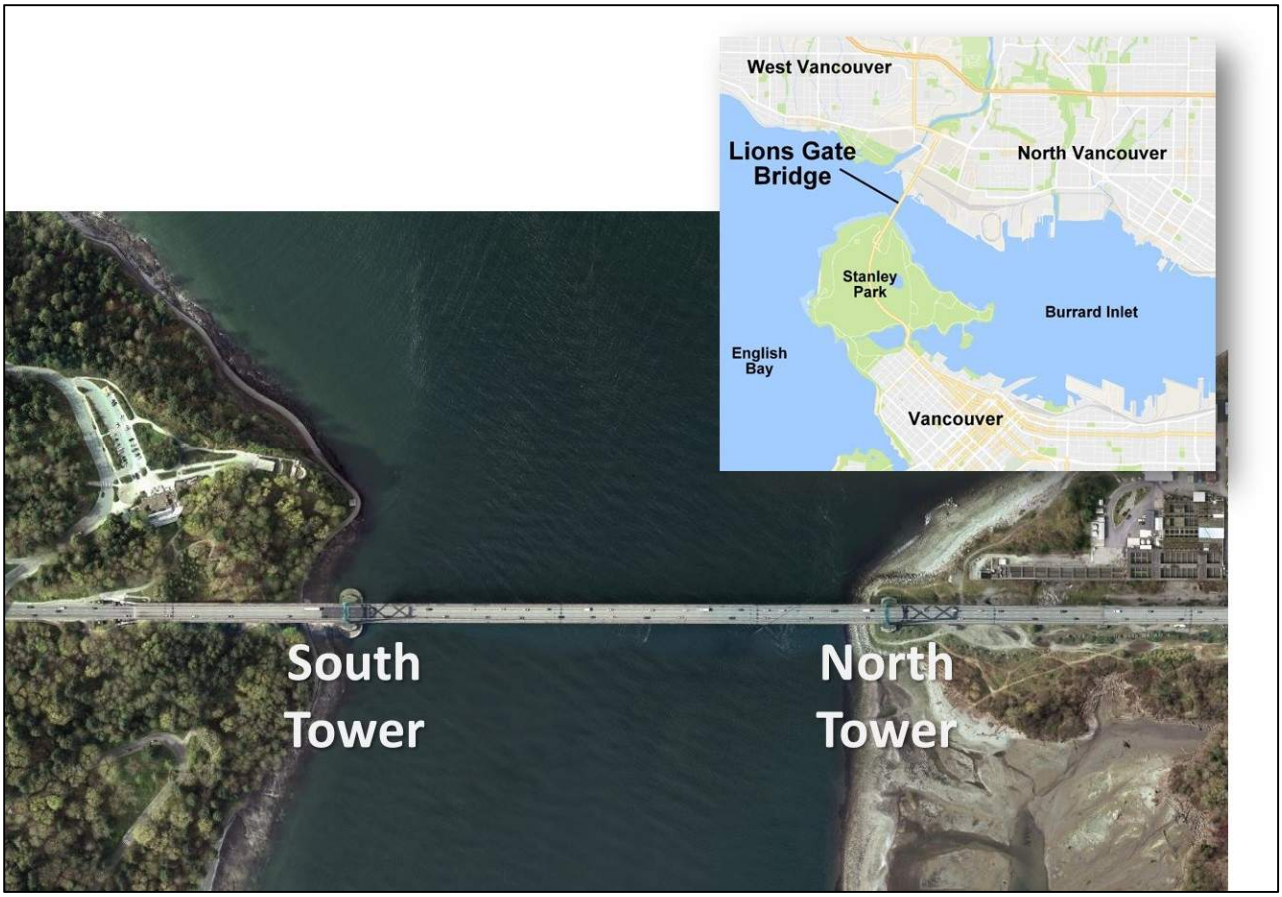



**Figure 1-2: Location of Lions Gate Bridge**

**Figure 1-3: South Tower Pier Protection – West Elevation at Low Tide**

The 1997 report **(3)** on the overall bridge concluded that the vessel collision risks to North Tower and the pedestal of the South Tower were low. Similar to earlier reports, the steel tower legs of the South Tower were identified as being vulnerable to a potential cruise ship bow impact above the protection collar. However, the quantified risks for the structure determined an Annual Frequency of Collapse (AFC) return period of 11,300 years, achieving the Code-required risk threshold of 10,000 years for Class I bridge of critical importance.

In 2000-2001, the bridge underwent a major renewal including seismic upgrades and an outright deck replacement.

## 1.3 OVERVIEW OF RISK ANALYSIS PROCESS

### *1.3.1 GENERAL REQUIREMENTS*

The vessel collision procedures and requirements in the Code (4-6) represent a simplification of a very complex problem involving ship design and operations, bridge design and response to extreme load events, the waterway and navigation channel layout, and a variety of environmental issues. Many of the Code provisions are based on lessons learned from historical accidents in which vessels impacted bridges as they were transiting the waterway in the vicinity of a bridge during normal merchant marine operations. The primary purpose of the Code's vessel collision provisions is to reduce the risk of bridge superstructure collapse to an acceptable level in the event of a vessel collision. Significant damage to secondary bridge structure components is permitted provided that alternative load paths and redundancy exists in the structure such that the superstructure does not collapse under the design impact event and the damage sustained is repairable.

The Code provides two alternative design methodologies (Methods I and II) in establishing criteria for vessel collision. **Method I** of the Code is a relatively simple, semi-deterministic procedure for selecting a design vessel and subsequently computing collision impact loads. The procedure is less accurate (and usually more conservative) than other methods and is, therefore, not recommended for final design of critical bridges. However, Method I procedures are useful in defining boundaries of the navigation zone used in a subsequent Method II risk analysis. Method I procedures are also useful in providing an initial assessment of the magnitudes of impact forces while input data for the significantly more complicated Method II risk analysis procedures are being collected and analyzed.

**Method II** is a probability-based risk analysis procedure that can be used both for directly assessing the risk of collapse from vessel impact and to develop vessel impact criteria for design. Using Method II procedures, a mathematical model is developed to estimate the annual frequency of bridge collapse based on the bridge pier/span geometry, ultimate pier strength, waterway characteristics, and the characteristics of the vessel fleet transiting the channel. The estimated risk of collapse can then be compared to predetermined acceptance criteria. Unless otherwise approved by the bridge owner for special situations, Method II is the recommended analysis procedure that should be used for all major bridges crossing navigable waterways.

The risk analysis presented in this report is based on the Method II procedures of the Code.

### *1.3.2 PROJECT APPROACH AND RISK MODEL DEVELOPMENT*

The estimate of potential bridge collapse due to vessel collision in the Method II risk model includes consideration of four general risk components: (1) a vessel approaching the bridge becomes aberrant; (2) the aberrant vessel impacts a bridge element; (3) the bridge element that is hit fails; and **(4)** potential protection factors based on bridge location. The Code risk equation is shown in **Equation 1**, below:

$$AFC = (N)\ (PA)\ (PG)\ (PC)\ (PF)\ (GF) \quad \text{(Eq. 1)}$$

where:

- AFC = Estimated annual frequency of bridge collapse due to vessel collision;
- N = Annual number of vessel trips classified by type, size, and loading condition (loaded or ballasted/empty), which can strike the bridge based on water depth and bridge clearances;
- PA = Probability of vessel aberrancy (*how often does the vessel go off-course?*);
- PG = Geometric probability of a collision between an aberrant vessel and the bridge pier or span (*if the vessel goes off-course, will it hit part of the bridge?*);
- PC = Probability of bridge collapse due to a collision with an aberrant vessel (*if it is hit, will the bridge collapse?*);
- PF = Protection factor considering the probability of collision between an aberrant vessel and bridge (*are there land masses or structures to protect the bridge from collision?*); and
- GF = Growth factor to account for future increase in annual number of vessel trips. This is typically projected to the mid-life of the bridge to compute an average lifetime risk.

Once the input information for the analysis has been collected and developed, the risk calculations can be completed by using programs such as Microsoft Excel and Mathcad to automate the repetitive/iterative analysis process. As illustrated in **Figure 1-4**, the analysis is typically conducted in a matrix or table. In the first column, various types and sizes of ships/barges are arranged in rows in order of decreasing size. Values for the various risk components are then computed for each specific vessel type and an AFC calculated for each row. This analysis is performed for each bridge pier and/or superstructure span as appropriate for the project as well as for vessels transiting both inbound and outbound (which can have differing speeds and water current conditions depending on transit direction). Once each bridge pier or span component has been computed, the annual frequency of collapse of the total bridge can then be obtained by summing the AFC's of each bridge component, vessel, and transit path in the analysis. The inverse of the annual frequency of collapse (1/AFC) represents the return period (in years) of the failure event. In general, the results of the risk analysis shown in this study are reported in terms of the estimated return period – which are easier to understand than the very small decimal fraction values associated with AFC.

Design vessels for collision evaluation and potential mitigation design are selected based on the bridge importance classification, waterway characteristics, vessel fleet characteristics, and crossing structure characteristics in accordance with the Code procedures.

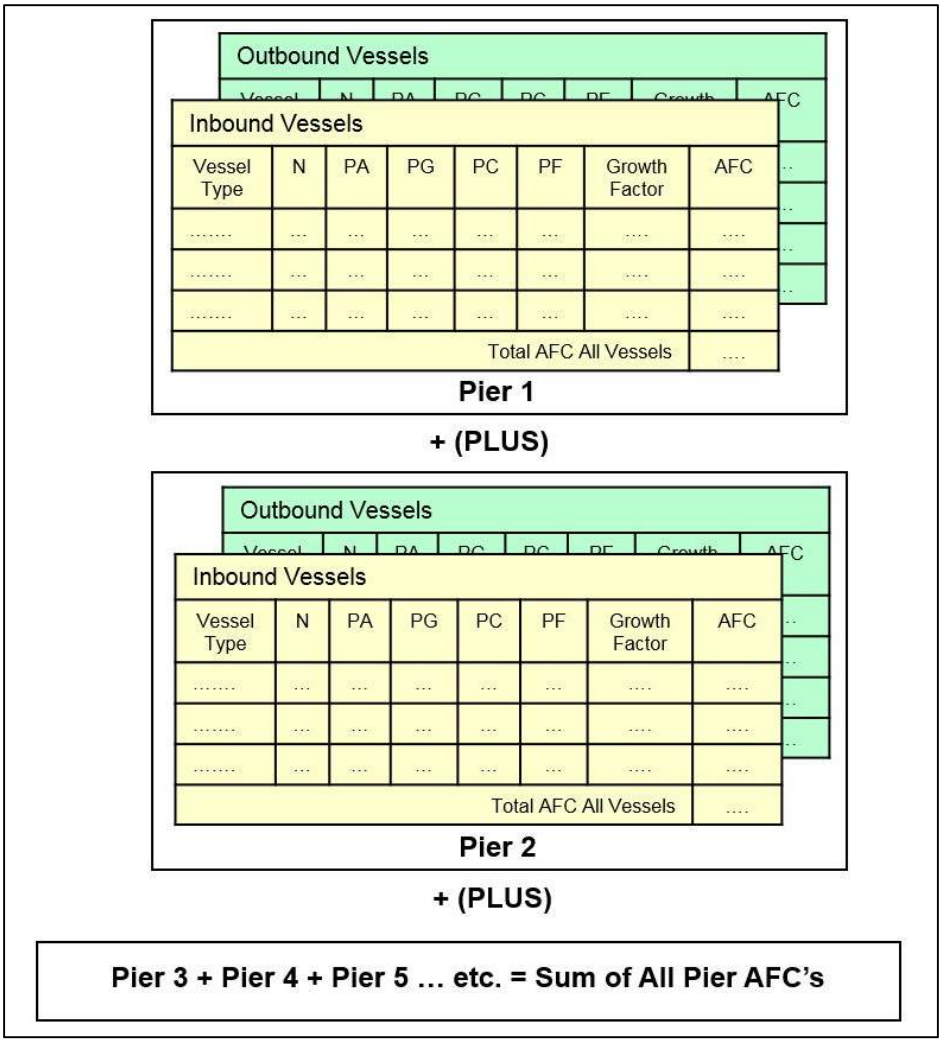



**Figure 1-4: Risk Model Development**

### *1.3.3 BRIDGE IMPORTANCE CLASSIFICATION*

All waterway crossings are not equally important to society. Crossings are usually classified based on social/survival and strategic highway network considerations. The social/survival evaluation for bridge crossings is primarily concerned with the need for civil defense, police, fire department, or public health agencies to respond to an emergency that might exist on opposite sides of a crossing. For highway bridges crossing navigable waterways, the Code requires that they be classified as either a Class I bridge (critical/essential) or a Class II bridge (regular) bridge as shown below:

- **Class I** bridges are of critical importance, including those that must remain open to all traffic after a vessel collision. The maximum annual frequency of collapse for the whole bridge shall be 0.0001, which is a return period of 1 in 10,000 years.
- **Class II** bridges are of regular importance, including those that must remain open to emergency and security vehicles after a vessel collision. The maximum annual frequency of collapse for the whole bridge shall be 0.001, which is a return period of 1 in 1,000 years.

For purposes of this study the Lions Gate Bridge was classified as a Class I (Critical) bridge with a desired return period of 1 in 10,000 years for collapse due to potential vessel collision. It should be noted that the above-mentioned bridge collapse return period criteria does not imply that the bridge is expected to last 10,000 or 1,000 years, but rather that during the normal service life of the structure (typically 100 years) the risk of collapse due to a vessel collision will be very small.

## 1.4 OVERVIEW OF HISTORICAL VESSEL ACCIDENTS

Vulnerability of critical infrastructures to extreme events have made headlines worldwide in the past decades due to structural failures, loss of life and financial damage associated with earthquakes, hurricanes, storm surge and waves, tsunamis, flooding and scour, vessel collisions, and terrorist attacks. For critical bridges, the risk and magnitude of such extreme events is often the controlling load case for the structure design.

The 1980 collapse of the Sunshine Skyway Bridge was a major turning point in awareness and increased concern for the safety of bridges crossing navigable waterways. Investigations and research subsequent to the Skyway and other major bridge accidents worldwide ultimately led to the development of the AASHTO Guide Specification and Commentary for Vessel Collision Design of Highway Bridges, 1st Edition, American Association of State Highway and Transportation Officials (AASHTO) in 1991. For the first time, this landmark publication provided the bridge design community the ability to evaluate the risk of vessel collision and estimate the magnitudes of impact forces associated with ship and barge collisions. A second edition of the Guide Specification was developed by AASHTO in 2009 **(5)** to update and incorporate lessons learned from the use of the original 1991 Guide Specification and incorporate results from barge and ship collision research conducted since the original vessel collision publication. The 1991 AASHTO Guide Specification was the primary basis for vessel collision requirements included within the Canadian Highway Bridge Design Code (CAN/CSA-S6-14), Section 3.14 and Annex A3.3 **(4)**.

The Second Narrows CN Rail Bridge across Burrard Inlet was struck by the cargo ship Japan Erica carrying logs in October of 1979 as it attempted to transit the harbour during heavy fog. The impact knocked an approach span adjacent to the main span section of the rail bridge into the water (**Figure 1-5**). The rail bridge remained closed until March 4, 1980. The rail bridge was constructed in 1968 and replaced the original bascule rail/highway bridge built in 1925 which had been hit by vessels several times and collapsed twice due to vessel collision. Subsequent to the 1979 accident, the VFPA in cooperation with the Coast Guard, PPA and other maritime stakeholders, imposed rigorous vessel operating restrictions for vessels transiting the Second Narrows waterway in the vicinity of the rail bridge.

A railroad swing bridge (Queensborough Railway Bridge) crossing the Fraser River in New Westminster, British Columbia was struck by a gravel barge under tug assistance on June 28, 2011. The Transportation Safety Board (TSB) of Canada determined that a fatigued tug master and an inexperienced mate were factors that led to the collision. The tug master apparently handed over the helm to the mate prior to a critical maneuver on the Fraser River with which the mate was unfamiliar. The tug master remained in the wheelhouse, but fell asleep. The bridge center swing span and protection pier sustained extensive damage. The bridge was inoperable for two months, causing major disruptions to railway and river traffic. Another barge impact in the area occurred on December 26, 1975 when the log barge Swiftsure Prince broke loose from its moorings at Pacific Coast Terminals and drifted upstream striking the New Westminster Railway Bridge. The collision sent the entire main fixed span into the river and caused major disruptions to both railway and river traffic.

It is important to note that there have been no vessel collision accidents with the Lions Gate or Ironworkers Memorial Bridges (both highway bridges). There have been no vessel collision incidents with the CN Rail Lift Bridge since the Traffic Control Zone-2 (TCZ-2) was implemented at Second Narrows, shortly after the Japan Erica incident in 1979.

A. Existing Rail Lift Bridge: 1979 Collapse – MV Japan Erica (22,000 DWT Cargo Ship)

B. Original Rail Bascule Bridge: 1930 Collapse - SS Losmar (Cargo Ship)

C. Original Rail Bascule Bridge: 1930 Collapse - Pacific Gatherer (Barge)

**Figure 1-5: Second Narrows Rail Bridge Collisions, Vancouver, B.C.**

# 2 WATERWAY CHARACTERISTICS

The Lions Gate Bridge crosses the First Narrows entrance into Burrard Inlet and Vancouver Harbour – which for marine navigation purposes is easily accessible and navigable by ocean going ships as far as Port Moody at the head **(9)**. The fixed highway bridge has a vertical clearance under the center of 61m. The controlling depth of the approach channel through the narrows is 15m at low tide with a navigable width of 305m. Commercial vessels (ships and barges) passing under the LGB are transiting to and from the Port of Vancouver (PoV).

The PoV is Canada's largest port, supporting close to one in every five dollars of trade in goods that flow through the country and offers the broadest range of cargo-handling options of any port in North America. As established by the Government of Canada pursuant to the Canada Marine Act, the PoV is under the jurisdiction of the Vancouver Fraser Port Authority (VFPA) which is responsible for the stewardship of federal port lands in and around Vancouver, British Columbia.

The VFPA operates across five business sectors: automobiles, breakbulk, bulk (dry and liquid), container and the passenger/cruise ship industry. The port facilitates trade with more than 170 world economies, and handled 138 million tonnes of cargo in 2015 valued at $200 billion. Almost 95 per cent of the port's total volume serves Canadian import and export markets. A map of the major marine terminal locations in Vancouver Harbour is shown in **Figure 2-1**. Detailed information about the VFPA and PoV facilities, including all requirements and restrictions for vessels operating within Vancouver Harbour, are contained in the VFPA's Port Information Guide **(10)**.

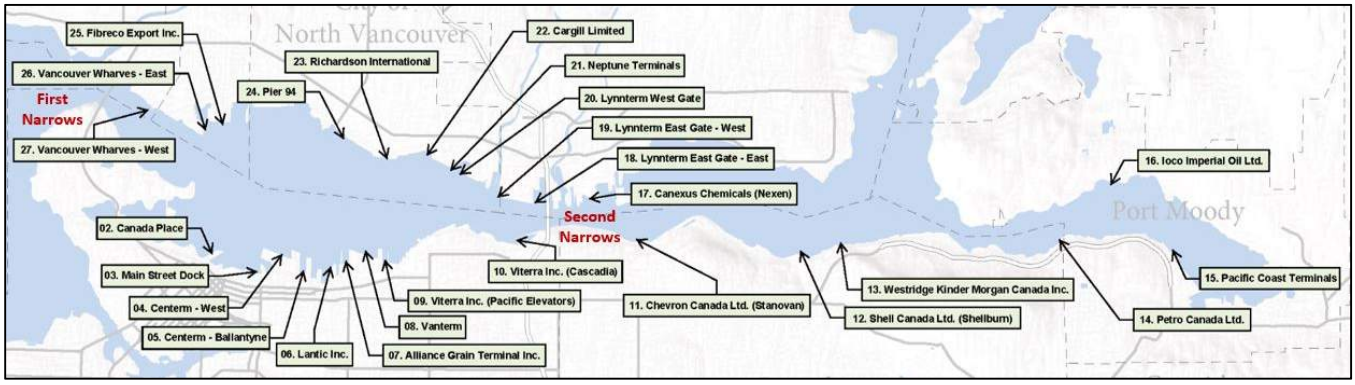



**Figure 2-1: Port of Vancouver (PoV) Major Marine Terminal Location Map**

## 2.1 BRIDGE LOCATION AND CHANNEL ALIGNMENT

A plan view of the Lions Gate Bridge superimposed on a section of the Vancouver Harbour nautical chart (Western Portion Chart # 3493) is shown in **Figure 2-2**. Added to the map are the typical vessel transit paths for inbound and outbound vessels and additional bathymetry near the bridge. Inbound vessels make a relatively sharp turn on their approach to the LGB, whereas outbound vessels pass under the bridge on a straight tangent alignment. The navigation envelope established by the VFPA for vessels with a beam (width) of 45.5m or less is a vertical clearance of 56.572m above the Higher High Water Large Tide (HHWLT) (El 5.0m) and a horizontal clearance of 157m as shown in **Figure 2-3**.

The navigation envelope values are adjusted for very large vessels with beams of 50m to a vertical clearance of 56.268m and a horizontal clearance of 177m. An adjustment is also made for the very large Solstice Class cruise ships where the vertical clearance is 56.572m and the horizontal clearance is 142m. Vertical clearances within the navigation envelope were established by the VFPA based on a 2m clear distance between the bottom of the bridge structure and the top of the navigation clearance envelope.

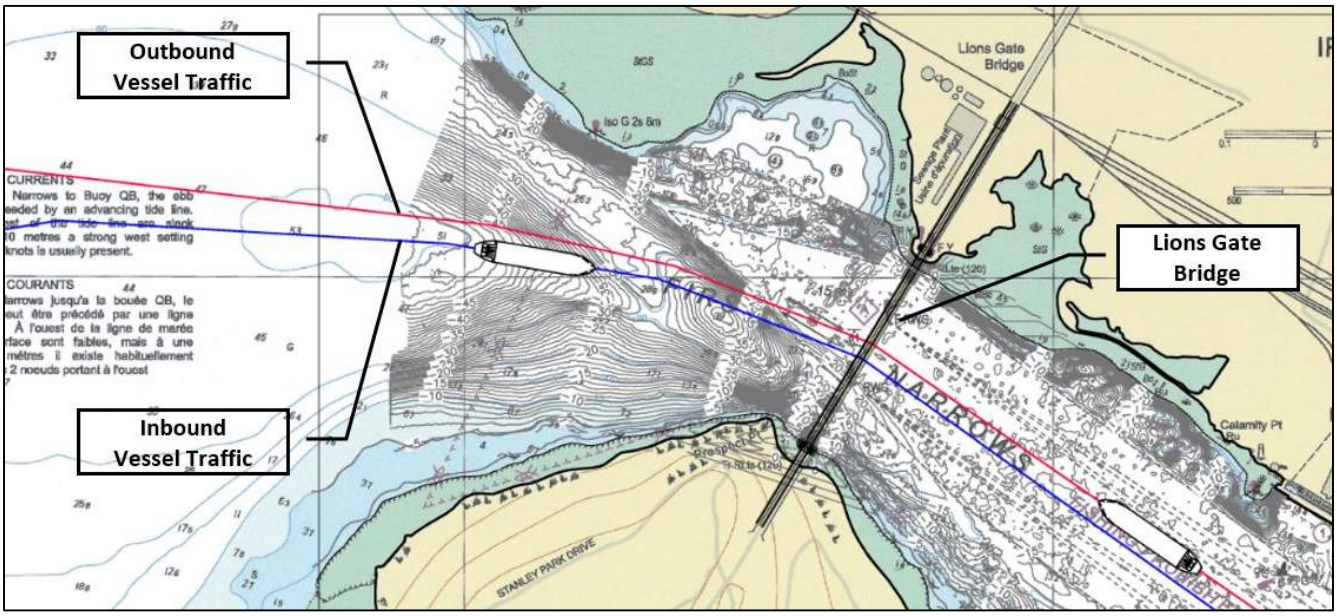



**Figure 2-2: LGB Vicinity Map**

## 2.2 FIRST NARROWS BATHYMETRY

In addition to the water depths shown on the nautical charts, supplemental bathymetry was provided by the VFPA. A supplemental topographical survey was also conducted as part of this study at the North Tower to define the existing rock berm elevations. **Figure 2-4** shows the bathymetry at the bridge; a closer view at the South Tower is shown in **Figure 2-5.** The seabed directly west and east of the tower is shallow, such that vessel grounding would occur before reaching the structure. However, the seabed drops rapidly north of the tower foundation approximately along the centre line of the bridge. Depending on tide level, there is the potential of a vessel impact with the South Tower from that direction; prior to the vessel grounding. The bathymetric data used in the study is detailed hydrographic sounding data provided by the VFPA. Water depths used in these figures and throughout this study are referenced to Chart Datum (CD) where elevation "zero" is the lowest normal tide. Vertical navigational clearances are referenced to the distance above Higher High Water Large Tide (HHWLT) elevation.

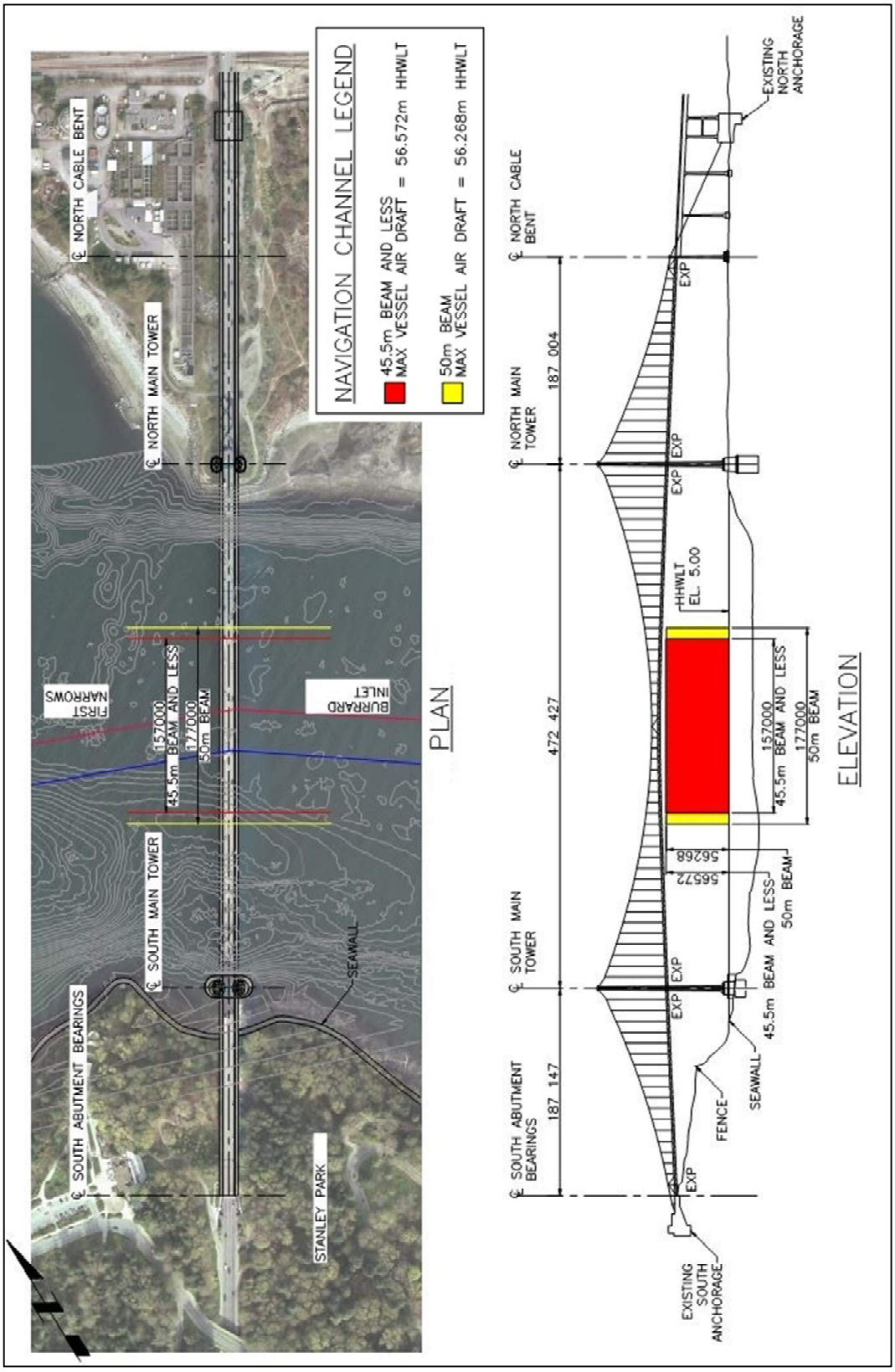



**Figure 2-3: LGB General Configuration and Navigational Channel Clearances**

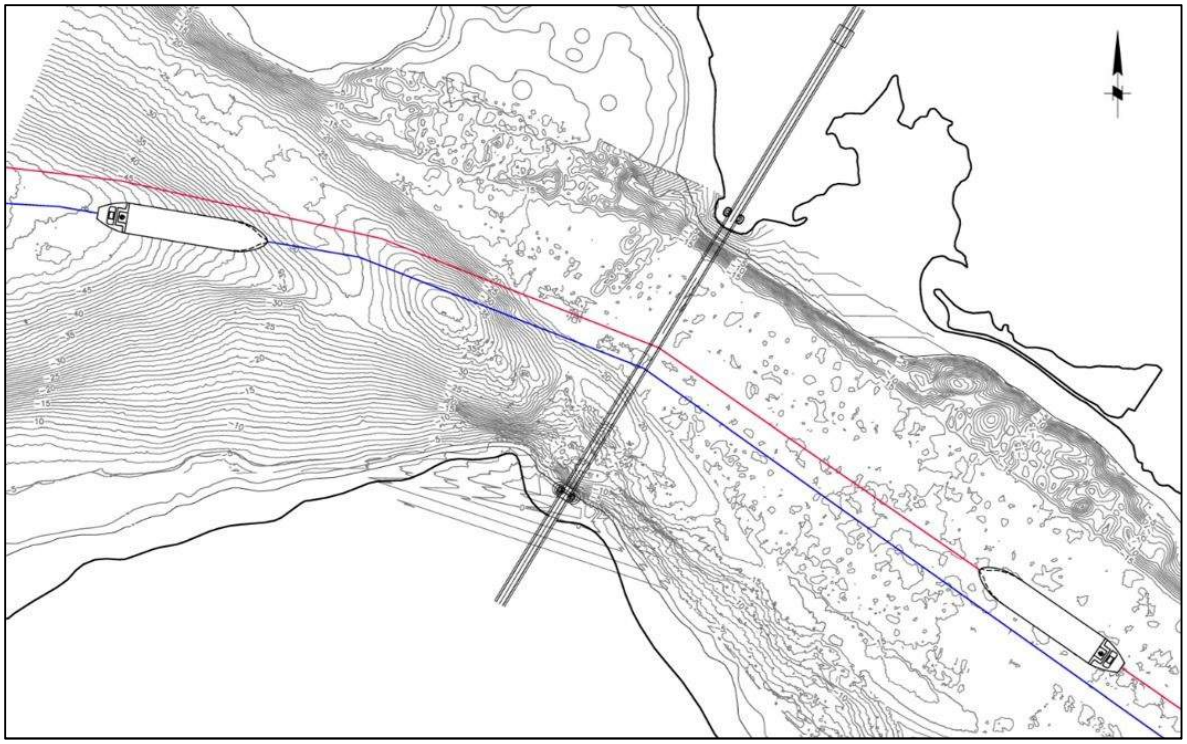


**Figure 2-4: Bathymetry Map**

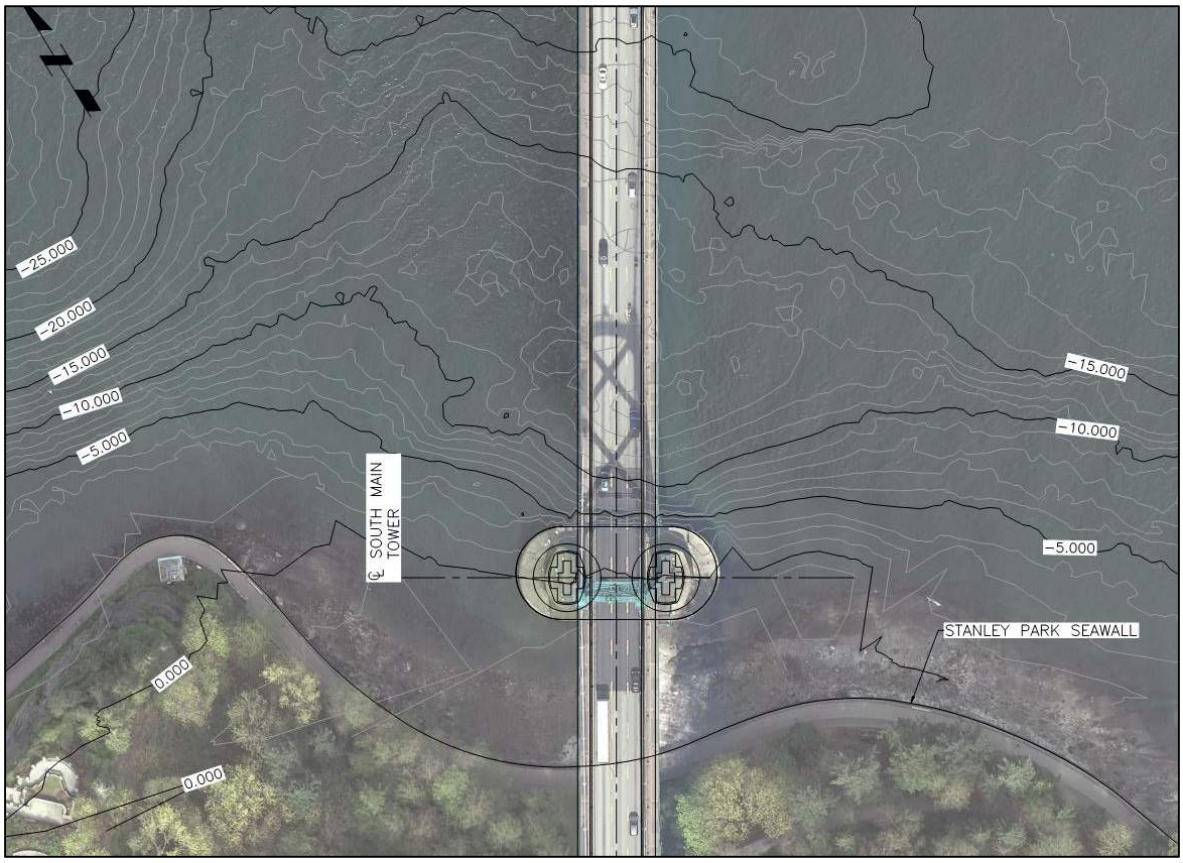



**Figure 2-5: South Tower Bathymetry**

## 2.3 TIDAL LEVELS AND CURRENTS

Tidal parameters for Burrard Inlet are summarized in **Table 2.1** based on Vancouver Tide Tables and data developed as part of this study. Vancouver experiences a mixed semidiurnal tide cycle: two high and two low tides of different size per day. The maximum tidal range in a cycle occurs during "spring tides" which occur twice per lunar month and can be as great as 5m.

**Table 2.1: Tidal Elevations at Vancouver Harbour**

| TIDE LEVEL | ELEVATION (M) |
|---|---|
| **Extreme Highest Water (EHHW)** | 5.60 |
| **Higher High Water Large Tide (HHWLT)** | 5.00 |
| **Higher High Water Mean Tide (HHWMT)** | 4.40 |
| **Mean High Water (MHW)** | 4.20 |
| **Mean Water Level (MWL)** | 3.10 |
| **Mean Low Water (MLW)** | 2.00 |
| **Chart Datum – CD** | 0.00 |
| **Lower Low Water Mean Tide (LLWMT)** | 1.10 |
| **Lower Low Water Large Tide (LLWLT)** | -0.10 |
| **Extreme Lowest Low Water (ELLW)** | -0.30 |

In accordance with Ministry policy, an adjustment for potential sea level rise due to climate change was included in the risk analysis and for developing mitigation concepts. The adjustment for sea level rise was projected 25 years, consistent with the mid-point of the 50-year study horizon of the bridge. The Geological Survey of Canada (GSC) **(11)** provides tabulated values of sea level projections in major Canadian locations. For this study's base case analyses, an increase in water elevation due to sea level rise was based on the GSC's most conservative projected values for Vancouver, a 0.1m increase in the next 25 years.

A hydrodynamic model of Burrard Inlet was developed for this study to investigate the hydraulic changes caused by physical mitigation measures. This analysis is described in further detail in **Section 9.2** and **Appendix D**. For the existing condition at First Narrows, typical peak surface flows for both ebb (receding to the west) and flood (advancing to the east) tides are shown in **Figure 2-6** and **Figure 2-7,** respectively. Peak surface currents of 2.0-2.5 m/s (4-5 knots) are reported uniformly across the narrows in a direction roughly parallel to the vessel transit paths.

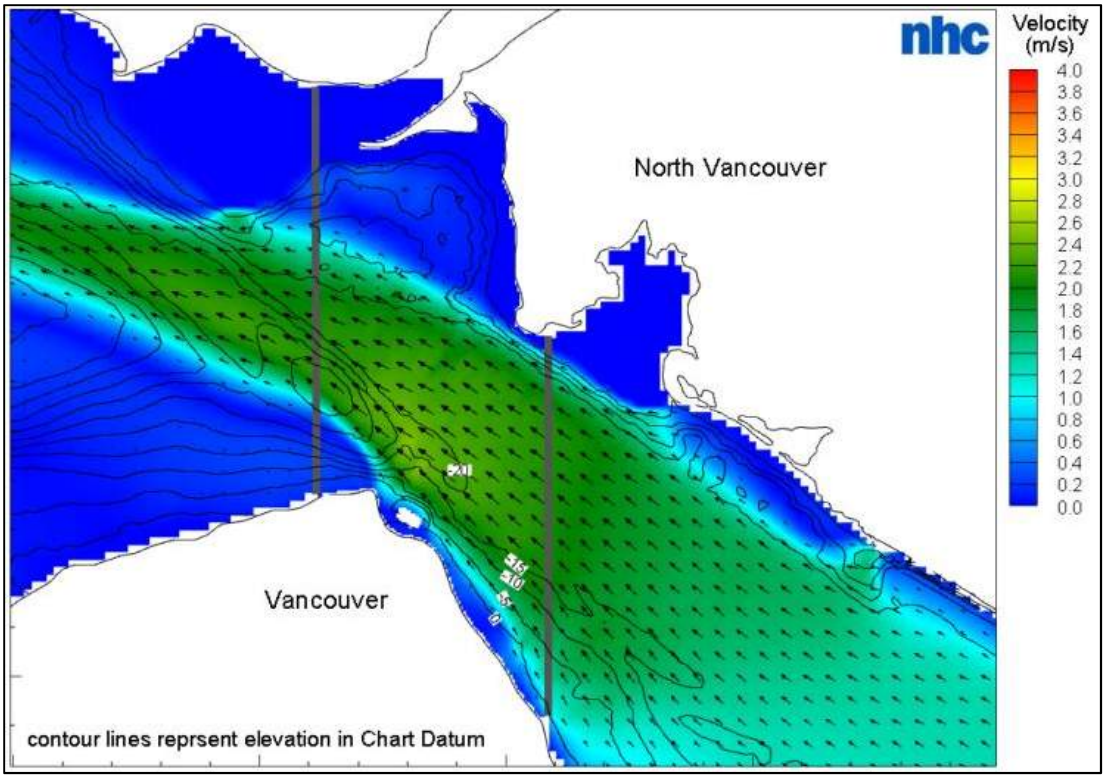



**Figure 2-6: Peak Surface Velocities at First Narrows – Existing Conditions – Ebb Tide**

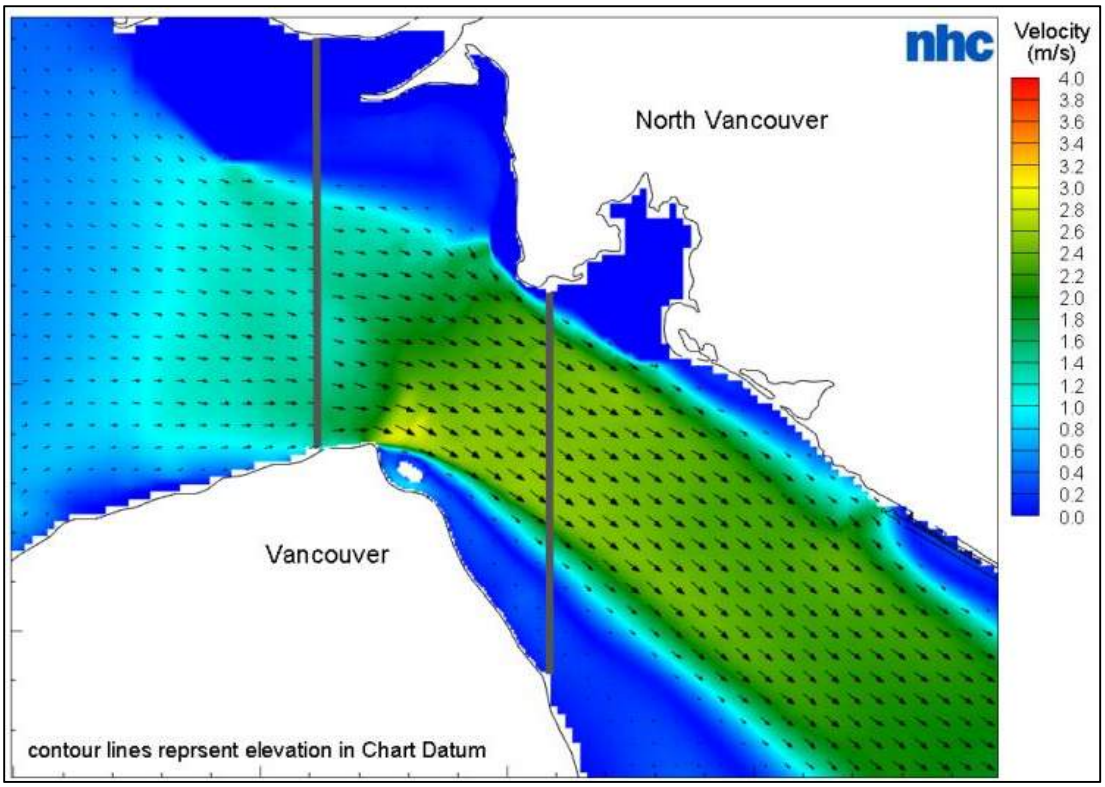



**Figure 2-7: Peak Surface Velocities at First Narrows – Existing Conditions – Flood Tide**

## 2.4 PRACTICES AND RESTRICTIONS FOR VESSELS OPERATING IN THE PORT

A Vessel Traffic Services (VTS) system operated by the Canadian Coast Guard, Western Region, covers the harbour and its approaches **(9)**. Vancouver is located within Sector 3 of the Vancouver VTS and is administered by Victoria Traffic through the Coast Guard's Marine Communications and Traffic Services Centre (MCTS). A Traffic Separation Scheme (TSS) also exists on the East side of the entrance to Burrard Inlet as shown on the nautical charts.

The VFPA's Operations Centre is the primary point of contact for all vessels operating within the port and the VFPA's Port Information Guide **(10)** includes rules and regulations concerning: vessel notification, documentation and reporting; port description and navigation; port safety and security; nautical services and communication; port operations; and port services. The Guide also contains the vessel operating requirements for designated Traffic Control Zones (TCZ) within the harbour, including special requirements for vessels transiting the First Narrows (TCZ-1).

Pilotage is compulsory for vessels over 350 gross tonnage (GT) and is provided by the Pacific Pilotage Authority (PPA). The pilot boarding station is located near Victoria at a location known as Brotchie Ledge. Unless noted otherwise in this report, the pilotage requirement is fulfilled by a single pilot onboard the vessel (special circumstances noted below require two pilots onboard).

The vessel collision risk model included the following existing vessel operation practices and vessel movement restrictions at First Narrows:

- Maximum vessel transit speed is 10 knots without tugs and 7 knots with tethered tugs.
- Tankers in product (i.e. loaded) equal to or greater than 40,000 DWT utilize two pilots.
- Tankers in product (i.e. loaded) equal to or greater than 40,000 DWT require tethered tug assistance.

Other than the special requirements for loaded tankers shown above, all other vessels have historically transited First Narrows with only minimal restrictions. The VFPA has recently published requirements for the Traffic Control Zone "TCZ-1" at First Narrows **(10)**. These requirements formalize the navigation channel design, navigation envelope and the current operational practices for loaded tankers stated above. In addition, the TCZ-1 calls for tug assistance requirements for very large container ships (greater than 340m in length) and bulk carriers (greater than 250m in length) when currents are greater than 2 knots. Note that the vessel collision risk model in this report does not include the new TCZ-1 requirements for very large container vessels that may call on the port in the future. However, the TCZ-1 requirements for these larger vessels will not materially change the basic findings and conclusions of this risk analysis due to: (1) the deeper drafts associated with very large ships would result in their grounding before contact is made with the bridge pier locations, and (2) the number of annual trips by the very large vessels is relatively small when compared to the number of transits of the remaining vessel fleet passing under the bridge.

# 3 BRIDGE CHARACTERISTICS

## 3.1 STRUCTURAL CONFIGURATION

The total length of the Lions Gate Bridge including the north viaduct is 1,823m. The length of the suspension span portion of the bridge is 846m and includes the main span of 472m (**Figure 2.3**). The main span superstructure is a steel truss supported by suspension cables from the two main pier towers which have heights of approximately 111m above ground. The towers consist of twin steel structural legs supported on concrete pedestals. The concrete pedestal of the South Tower is founded on rock and the concrete pedestal of the North Tower is supported on a concrete caisson which is founded within the Capilano River deposits. The deck width is approximately 10.7m wide and supports three lanes of traffic, typically one in each direction and a middle counter-flow lane.

In 2000-2001, the bridge was extensively retrofitted including seismic upgrades and an outright deck replacement.

## 3.2 GEOTECHNICAL CONDITIONS

The concrete pedestals supporting the South Tower are founded directly on sandstone bedrock which is present at the tower location as a surface exposure or with a thin overburden mantle of cobbles, sand and gravel. The sandstone is part of a tertiary bedrock unit consisting predominately of sandstone, siltstone, shale and conglomerate with minor volcanic rocks, and is described in detail in the W.E. Hodge report of May 1987 **(12)**. Test holes completed in 1987 at the tower location determined that the surface sandstone is underlain by shale and that historical shear zones are present at the interface between the sandstone and shale resulting from tilting of the sedimentary rocks about 20 million years ago.

The concrete pedestals supporting the North Tower are supported on a caisson which extends into the layered gravel, sand, silt, and cobbles of the Capilano River deposits. These recent, post-glacial, Capilano deposits are loose to compact and are known to extend to depth and to cover deposits of glacial till.

## 3.3 PROTECTIVE BERM IN PLACE AT NORTH TOWER

A protective rock berm (similar to a protective island) was constructed around the North Tower in 1988 as a result of a vessel collision risk evaluation in 1984 **(1)**. The exposed location of the North Tower on the outside portion of the relatively sharp turn required by inbound vessels in the navigation channel resulted in an increased risk of potential vessel collision. The protective rock berm was constructed to reduce the risk of aberrant vessels from contacting the North Tower by causing vessels to run aground. Photos and an elevation view of the existing rock berm are shown in **Figure 3-1** and **Figure 3-2**. Surveys conducted as part of this study indicated some relatively minor settlement and reshaping of the original rock slope (probably due to storm related wave action). **Figure 3-3** is a cross section of the rock berm showing the original slope in 1988 and the current surveyed slope.

The ability of the existing rock berm to prevent vessel contact with the North Tower was evaluated (and reconfirmed) as part of the current vessel collision risk analysis (see **Section 5**).

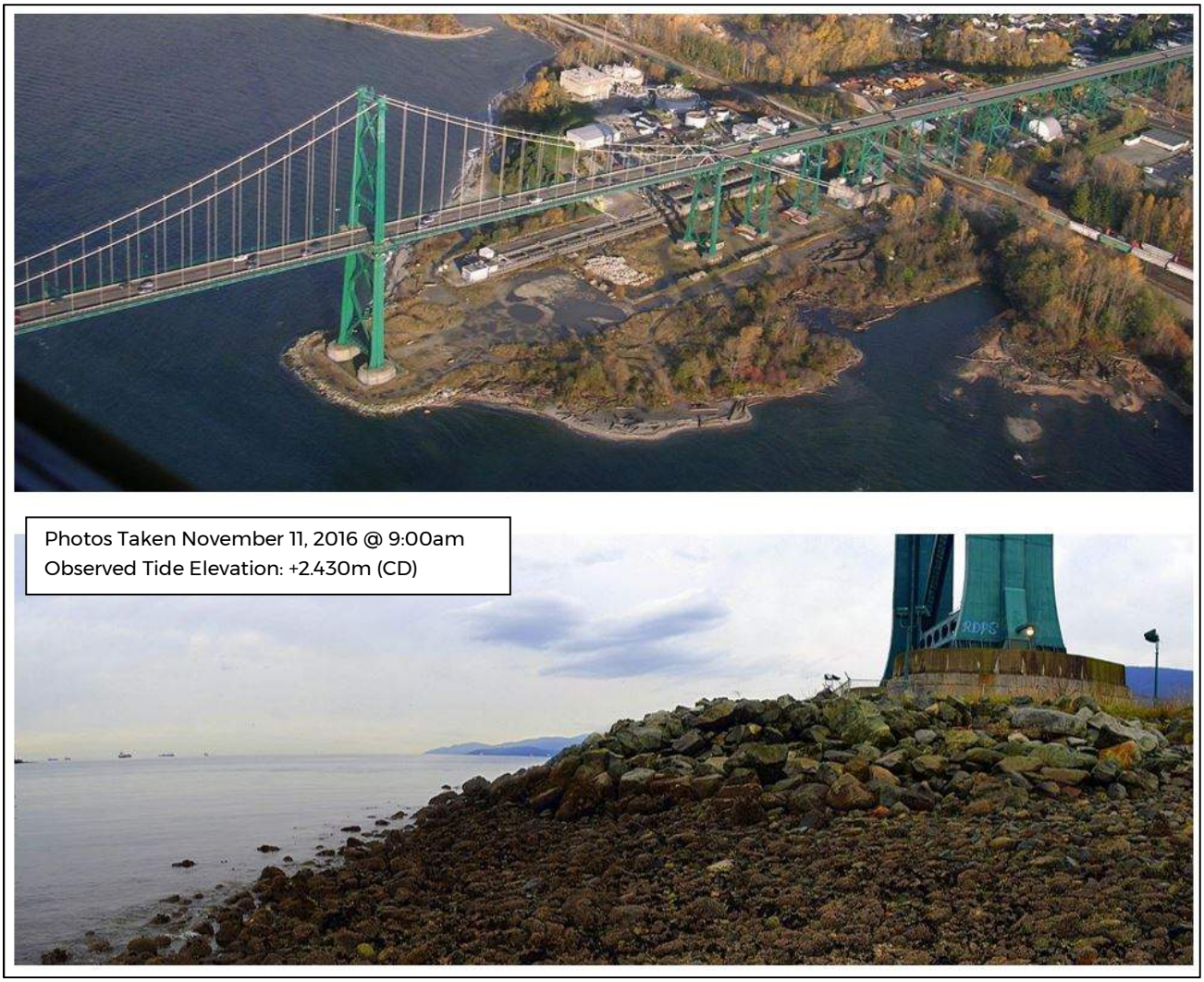



**Figure 3-1: North-Tower Protective Rock Berm Photos**

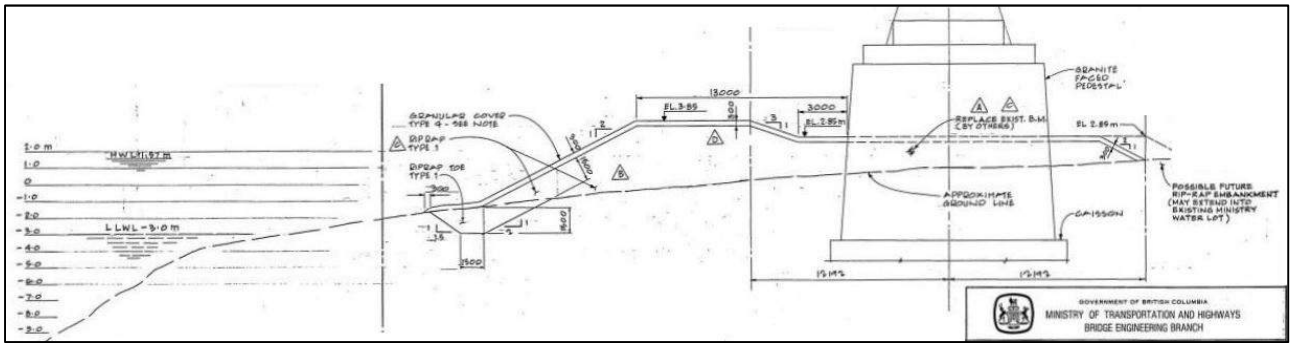



**Figure 3-2: North Tower Protective Rock Berm Plan and Elevation**

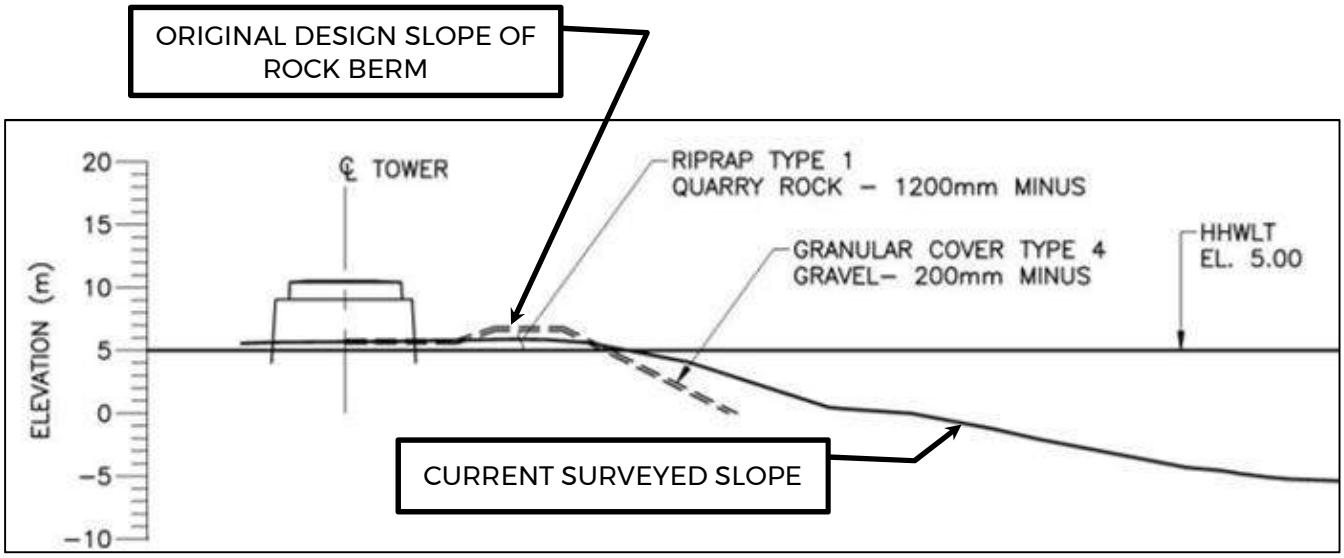



**Figure 3-3: North Tower Protective Rock Berm Surveyed Cross Section**

## 3.4 PROTECTIVE SUBSTRUCTURE COLLAR IN PLACE AT SOUTH TOWER

A protective concrete collar was constructed around the South Tower substructure foundation in 1988, recommended by the vessel collision risk evaluation completed in 1986 **(2)**. The concrete base of the tower was strengthened and a concrete collar was added above the base to strengthen the South Tower pedestal to withstand potential impact loads from aberrant vessels. Photos and plans of the existing concrete protective collar are shown in **Figure 3-4** and **Figure 3-5**.

The dimensions of the protective collar were developed to prevent contact of typical tankers and bulk carrier ship bows (which have relatively blunt bows) with the steel tower legs. The 1986 report identified a potential vulnerability of the steel tower legs to vessel contact by cruise ship bows above the water - which have relatively large bow overhangs. This current risk analysis study includes the evaluation of the potential vulnerability of the tower legs from modern container ships, general cargo ships and cruise ships which can also have large bow overhangs.

**Figure 3-4: South-Tower Protective Concrete Collar Photos**

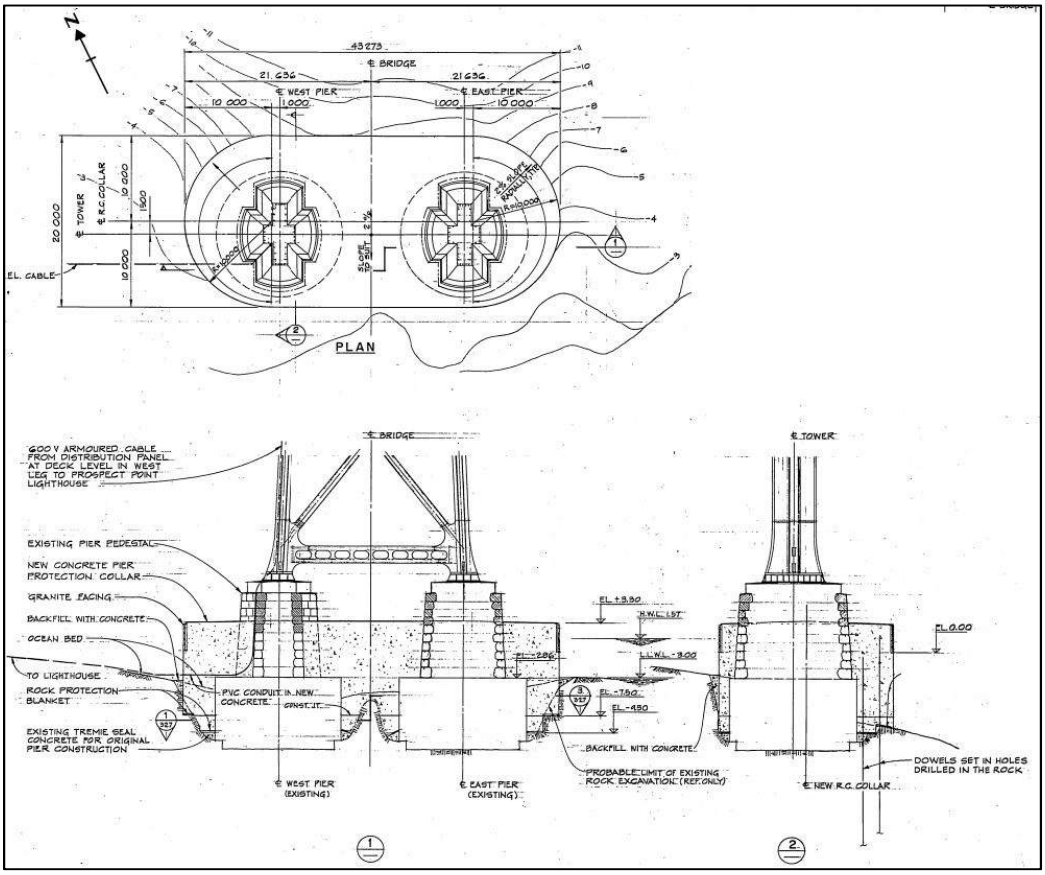



**Figure 3-5: South Tower Protective Concrete Collar Plan and Elevation**

## 3.5 BRIDGE RESISTANCE TO SHIP IMPACT

A key component of assessing the annual frequency of collapse (Eq. 1) is a probability of collapse (PC) which is based on the estimated impact force of the aberrant vessel (P) and the resistance strength of the bridge (H) to resist that impact force. The bridge resistance strengths for this study were based on values from previous studies of the Lions Gate Bridge **(1) (2) (3)**.

The North Tower foundation (concrete pedestal) has an estimated resistance strength of 33 MN. This resistance strength is about 20% of the force that would be generated by contact with a typical 80,000 DWT container ship. As noted, the North Tower is protected from vessel collision by a rock berm that stops the ship before contact is made with the pier effectively fully mitigating this risk.

For the South Tower, the upgraded pier foundation (concrete pedestal) has an estimated resistance strength of 173 MN. However, the steel tower legs are relatively thin-walled cellular members with minimal capacity for concentrated lateral loads. For ship collision purposes, their resistance to horizontal impact is low. For this risk analysis, therefore, the steel tower legs are assumed to provide no resistance in a ship collision event (H = 0 MN). In summary, the South Tower configuration has sufficient strength capacity for vessel contact near the waterline but is potentially vulnerable to vessels with a significant flare (overhang or rake) that may extend in front or to the sides of the bow, as illustrated in **Figure 3-6**.

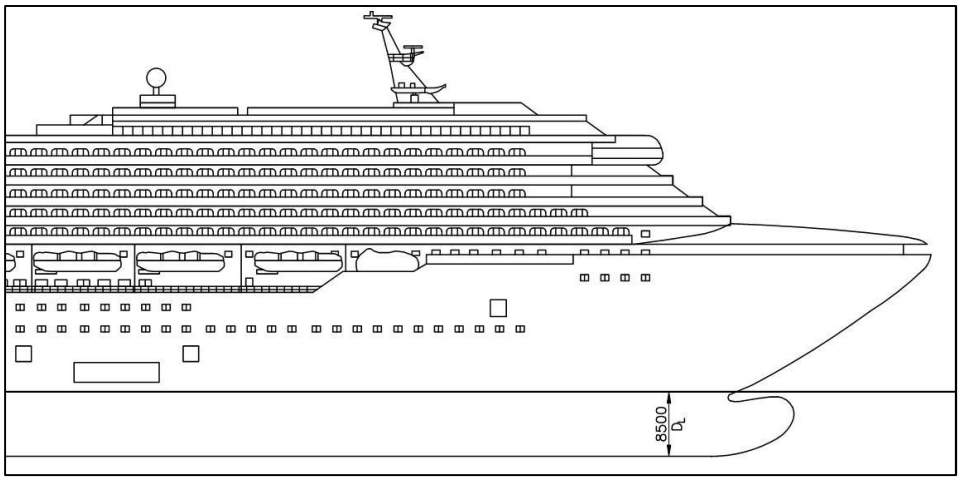



**Figure 3-6: Vessel Geometry with Significant Bow Flare**

## 3.6 DESIGN WATER DEPTHS

The ability of a vessel to contact a pier is limited by the available water depth in the near vicinity of the pier. Aberrant vessels with drafts less than the water depth could contact the tower, whereas vessels with a draft greater than the water depth run aground before contacting the tower. For the risk analysis, the design water depth was determined for each tower based on the existing bathymetry, tide elevation, allowance for aberrant vessels to potentially ride-up the slope of the existing rock before grounding, and an adjustment for potential sea level rise. Adjustments in water depth were also included in the risk analysis for vessels that might ride-up or plough through existing rock or soils even when their drafts were deeper than the available water depth. For both the North and South Tower, a detailed evaluation was conducted for vessels ploughing into and riding up the existing protection rock berm and rock sea floor, respectively (see **Section 5**). Based on this analysis, the design depth used in the risk analysis for the North and South Towers was increased by 2m.

At the North Tower, the existing ground (mudline) was set equal to El 5.0 due to the presence of the protective rock berm. The South Tower is located within a small cove of the First Narrows shoreline and the rock elevations near the tower vary considerably depending on the direction of the aberrant vessel (El -1.0 to -7.0 chart datum). For this study, a conservative rock elevation of El -7.0 was selected for the South Tower.

The Code recommends a water elevation based on Mean High Water (MHW) for use in ship collision risk analysis. This represents an (intentionally) conservative assumption in which all vessels transiting the waterway are assumed to transit at the MHW level (and not at lower water levels in a tide cycle). The use of MHW is considered appropriate for most waterways where the tidal range is relatively low. However, for waterways with large tidal ranges – such as Vancouver with a 5m+ tide range – the tide cycle is usually broken into increments with vessel transits occurring at each incremental water level. Ship collision analysis based on the use of multiple water levels in large tide range locations is considered significantly more accurate than the use of a single water level.

For the LGB, the analysis used four water levels to more accurately model the tide cycle. Discussions with the PPA indicated that vessel transits through First Narrows occur in a relatively uniform pattern throughout the tide cycle. As such, four water levels were selected based on equal tide increments between higher high and lower low water levels as follows: HHWLT = El 5.0m, El = 3.3m, El = 1.6m, and LLWLT = El -0.1.

## 3.7 ENVIRONMENTAL CONTEXT

Most of the seafloor around the South Tower is considered an intertidal or littoral zone in that it is above water at low tide and under water at high tide. As shown in **Figure 3-7**, this area includes many different habitats depending on the degree of submersion. The mid intertidal zone is regularly exposed by average tides and supports a mix of tide pool marine life, smaller organisms and terrestrial life. The lower intertidal (or lower littoral) zone is only exposed to air at the lowest of low tides and is primarily marine in character, supporting larger marine organisms (e.g., anemones, starfish, urchins, etc.), marine vegetation (e.g., seaweed), and some bird species (e.g., Great Blue heron). The subtidal zone is permanently submerged and supports marine fish and vegetation (e.g., kelp).

## 3.8 PUBLIC AND HISTORIC CONTEXT

The LGB is a landmark structure in Vancouver, well known to tourists and local residents. In 2004, the bridge was recognized as a National Historic Site of Canada due to its elegant design in a spectacular setting and its outstanding engineering achievement for its time. The towers are specifically identified as a key heritage element that define the character of the bridge, its value expressed through, "*its twin, tapered open work towers that consist of sections of flat and angled steel*" **(13)**. The south roadway approach to the bridge passes through the equally iconic Stanley Park. The park's seawall passes under the bridge deck, 30m south of the South Tower. The seawall is a multi-use path that, on sunny weekends, can have over 10,000 users a day (**Figure 3-8**) **(14)**.

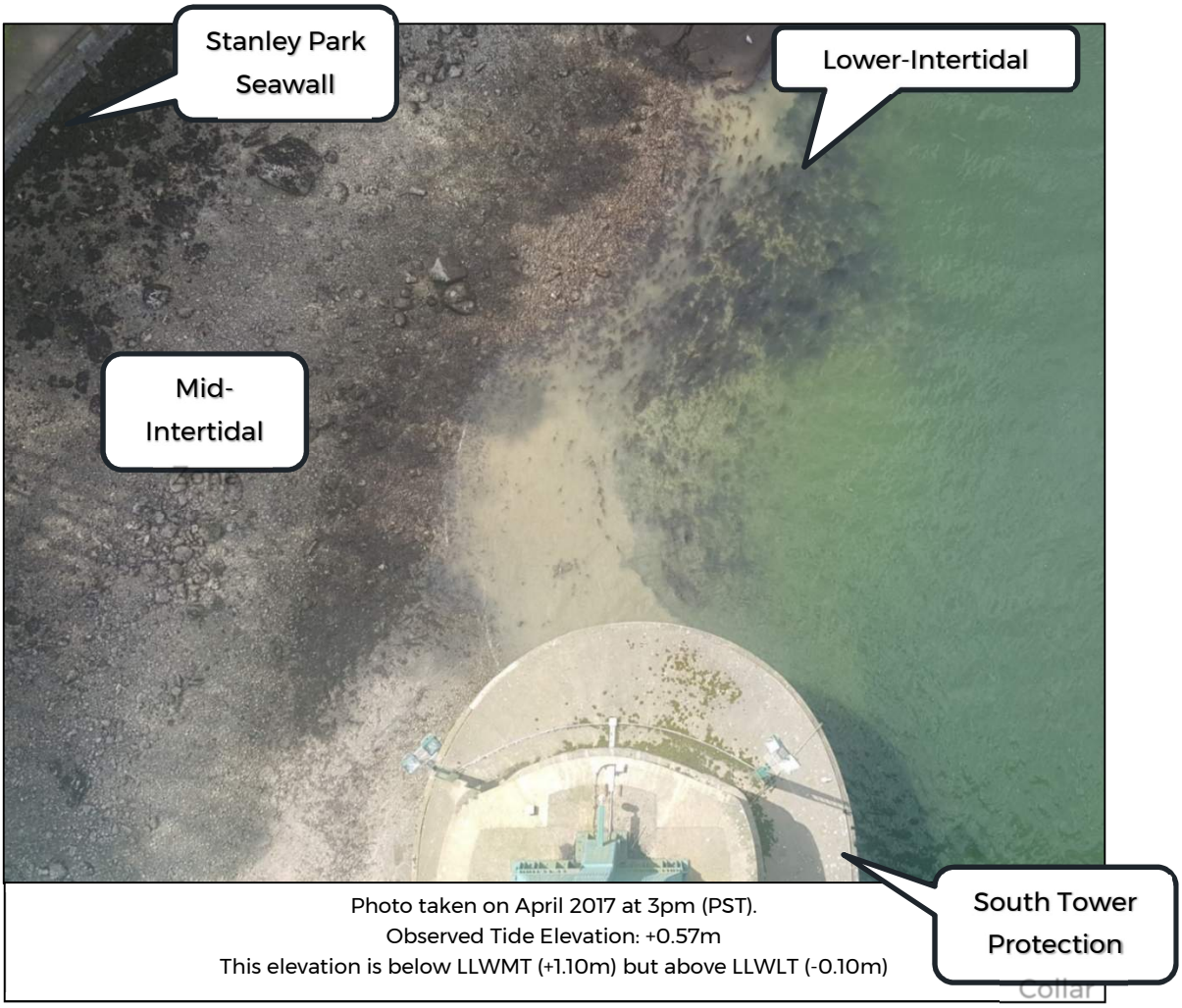



**Figure 3-7: Looking Down on the Seafloor at West Side of South Tower**

**Figure 3-8 Seawall on Sunday Afternoon in Summer**

# 4 VESSEL FLEET CHARACTERISTICS

The collision risk analysis is conducted by first determining the existing vessel fleet operating under the bridge and then projecting the number of annual transits (and sometimes size) of the vessels into the future to a year coinciding with the mid-point of the study's planning horizon. For purposes of estimating the annual frequency of collapse, the future fleet is used to represent the average fleet over the expected service life of the bridge. Due to the nature of the shipping industry, the type and sizes of vessels and the tonnage carried by vessels calling on a port often vary from year to year in accordance with national and global economic trends. For the Lions Gate Bridge, vessel transit data at the bridge location was collected and compared for the years 2014 and 2016. The data was then used to develop a "current" vessel fleet that is considered representative of the existing fleet that has been transiting under the bridge the past few years.

Characterization of ship traffic operating in the vicinity of the Lions Gate Bridge was developed utilizing historical data collected from shipborne Automatic Identification Systems (AIS) for the calendar years 2014 and 2016 for Vancouver Harbour. The AIS data was compared to vessel information in databases maintained by the VFPA and PPA to identify and correct occasional reporting anomalies or incomplete information for specific vessels. AIS information relates to encoded VHF signals broadcast from vessels over 300 tonnes containing information such as vessel position, maneuvering characteristics, loading conditions, and navigational status.

The raw AIS database includes various parameters describing each vessel such as: Maritime Mobile Service Identity (MMSI) identification number, vessel name, vessel type, status, speed, position, heading, beam (width), length overall (LOA), draft, and timestamp when data was collected. The broadcasted vessel transmissions are collected via satellites and terrestrial AIS base stations where the information can be stored and subsequently evaluated by specialized post-processing programs. It should be noted that current ship locations, including Vancouver Harbour, can be viewed real-time on a variety of websites available to the public.

AIS data provides a powerful tool in the risk analysis process because it provides an accurate historical snapshot of every vessel transiting the harbour at the specific location of the bridge with their type, size, drafts, location, and speed. Because AIS data is transmitted real-time at frequent time intervals, plots of vessel tracks can be developed to map the entire passage of a vessel within the harbour. **Figure 4-1** and **Figure 4-2** illustrate plots of annual tanker and container ship traffic within Vancouver Harbour for the year 2016.

## 4.1 VESSEL TYPES AND CATEGORIES

Based on the AIS data, the vessel fleet at Lions Gate Bridge was organized into 83 ship categories according to type of vessel and size based on 5,000 DWT (deadweight tonnage) increments. Cruise ship sizes are reported in terms of gross tonnage (GT) as well as their equivalent DWT (GT is a measure of the interior size of the vessel, whereas DWT is a measure of the weight of cargo a ship can hold). The vessel fleet consists of the following types and categories:

- **Bulk Carriers:** 30 Categories ranging from 20,000 DWT to 210,000 DWT
- **Tankers:** 16 Categories ranging from 15,000 DWT to 120,000 DWT (Aframax)
- **Container Ships:** 14 Categories ranging from 35,000 DWT to 120,000 DWT
- **General Cargo (GC) Ships:** 12 Categories ranging from 5,000 DWT to 60,000 DWT
- **Articulated Tug Barges (ATBs) - Tankers:** 2 Categories, 25,000 and 30,000 DWT
- **Cruise Ships:** 9 Categories ranging from 5,300 GT to 121,900 GT

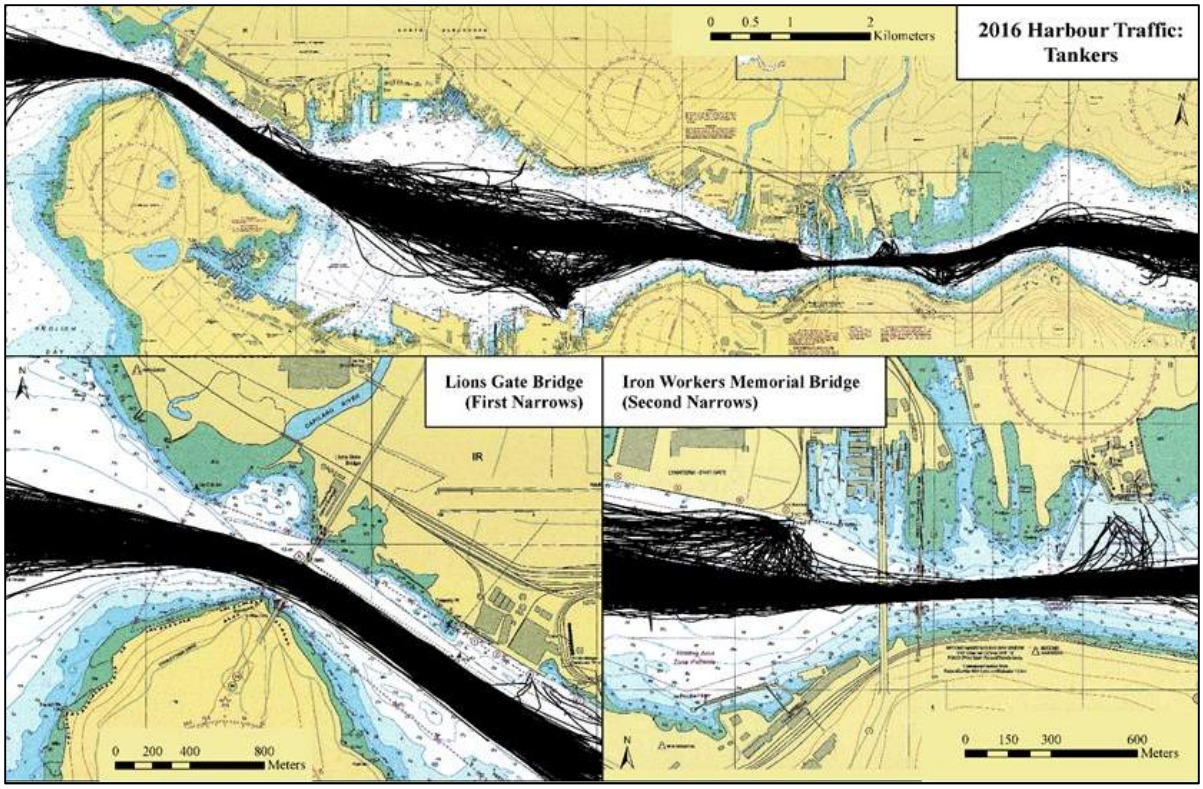



**Figure 4-1: AIS Tanker Vessel Tracks**

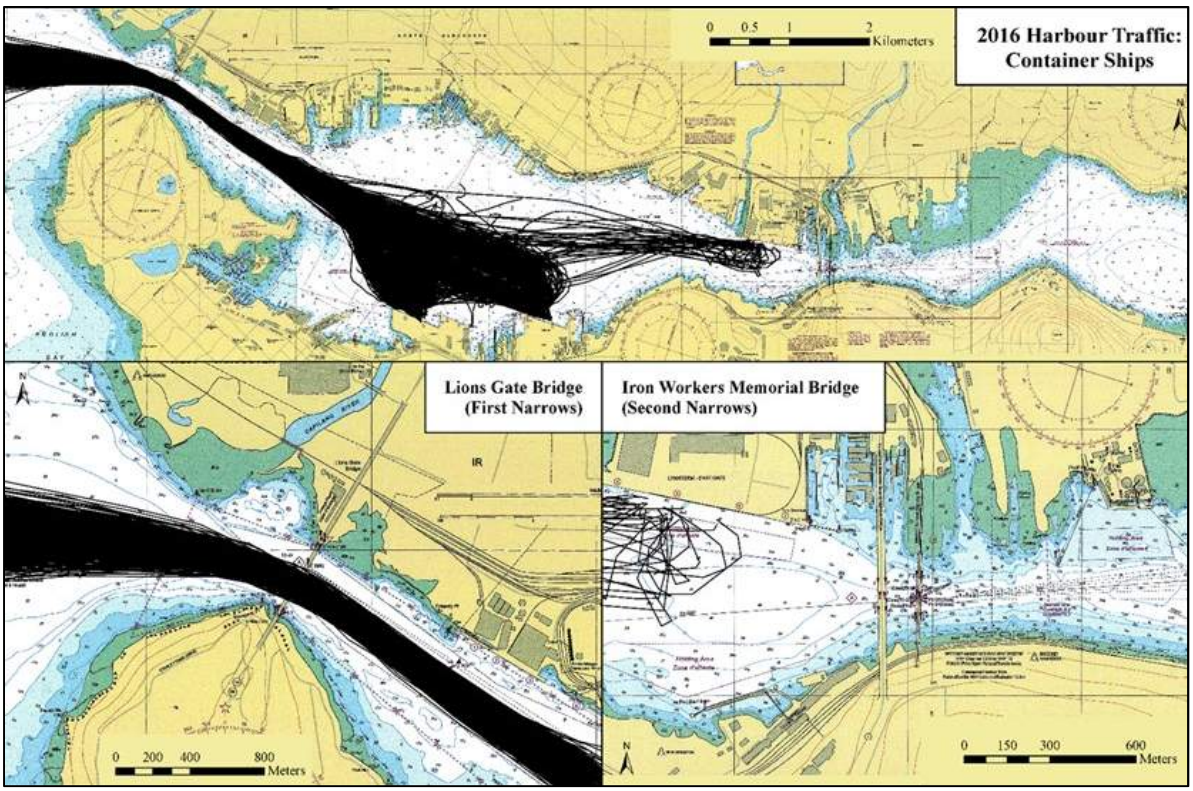



**Figure 4-2: AIS Container Vessel Tracks**

Small vessels transiting the harbour, including fishing, tugs, log booms, small barges, and recreational craft were not included in the risk analysis since their collision forces are relatively low and they are more maneuverable. Specialized vessels that operate in the harbour only on rare occasions were not included in the risk analysis since their numerical contribution to the risk analysis was negligible.

Photographs of representative vessels are shown in **Figure 4-3**. Details of the vessel fleet categories are shown in **Appendix A**. Each of the vessel categories has an assigned Vessel ID Number (from 1 to 83) for purposes of identifying them in the risk analysis.

Bulk carriers and tanker ships usually transit one-way loaded (either inbound/outbound or outbound/inbound depending on the cargo and marine terminal) and one-way ballasted when the ship is traveling without any cargo. Container ships, general cargo ships, and cruise ships usually transit loaded (or partially loaded) at all times.

According to the AIS and other information, the very large bulk carrier categories representing 185,000 – 210,000 DWT ships (Vessel ID's 1, 2 & 3) are transiting the LGB ballasted in both directions to moor at designated anchorage locations inside Burrard Inlet while waiting for berths at marine terminals located outside the harbour at Roberts Bank.

## 4.2 VESSEL CHARACTERISTICS

Vessel physical characteristics were developed for each ship category, including DWT, LOA (length overall), beam (width), drafts (loaded and ballasted), displacement, and the height of mast, deckhouse, and bow features of the ship (**Appendix A**). Although ship characteristics can vary widely (even for similar size DWT's), information from various sources were used to estimate typical representative values for the vessel characteristics for each ship category in this study:

- AIS data for the specific ships calling at the PoV in 2014 and 2016;
- Clarkson's World Fleet Ship Register;
- Q88 (Tanker Questionnaires Covering 75% of the World Fleet);
- Q88DRY (Bulk Carrier Questionnaire Database) ;
- Significant Ships (annual publication of the Royal Institution of Naval Architects);
- Canadian and AASHTO highway bridge codes;
- PoV Burrard Inlet Vessel Call Database; and PPA Vessel Assignment Database.

Ballasted (empty or light) ship transits often represent a significant component of vessel collision risk due to their relatively shallow draft when compared to the loaded ship draft. This allows them to potentially hit bridge piers located in shallower water where they might otherwise run aground if they had been fully loaded. **Figure 4-4** illustrates the typical geometry of a ballasted ship, where the drafts at stern and bow locations are significantly less than if the vessel were in a loaded condition. The ballasted drafts at the stern were developed from the vessel characteristic's sources above (in general the ballasted stern draft is approximately one-half of the fully loaded draft). The ballasted draft at the bow was estimated using a 1.5% slope of the bottom of the keel in accordance with International Association of Classification Services (IACS) and MARPOL IMO hull design guidelines.

A. Bulk Carrier (Bulkers)

B. Container Ship

C. Tanker

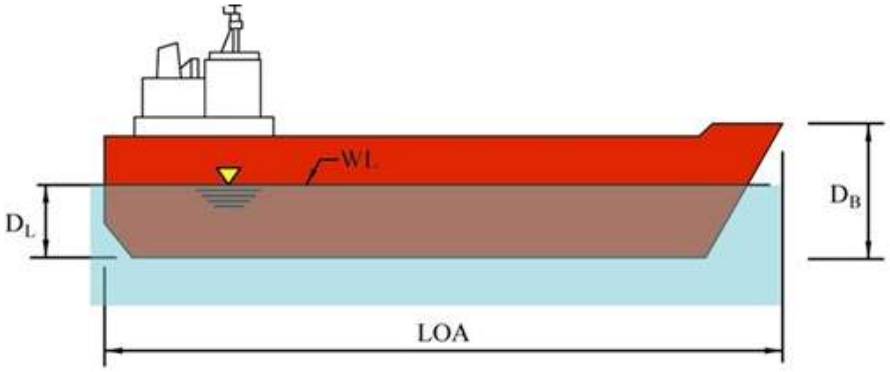
D. Cruise Ship

E. General Cargo Ship

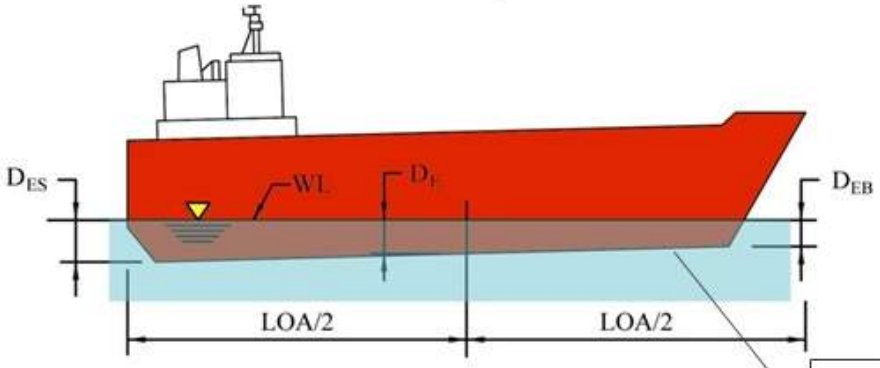
F. Articulated Tug Barge (ATB) - Tanker

**Figure 4-3: Vessel Type Photographs**

A. Bulk Carrier in Ballast Condition




a. Loaded Ship Profile.




b. Ballasted Ship Profile.

1.5% Slope of Keel

B. Typical Ship Profile: Loaded and Ballasted

**Figure 4-4: Ballasted Vessels**

## 4.3 VESSEL TRAFFIC (ANNUAL TRIP FREQUENCIES)

Annual trip frequencies for the existing and future (25-year projection) vessel fleets transiting under Lions Gate Bridge were developed for each vessel category. The frequencies are shown in **Table 4.1** and are summarized in **Table 4.2** for the base case scenarios. The existing vessel fleet makes 4,534 trips/year under the Lions Gate Bridge and is projected to grow to 6,337 trips/year in the future. Details for the annual frequency distribution for the base case analysis are shown in **Appendix A**.

As shown in **Table 4.2**, the majority of vessels in the existing fleet are bulk carriers (55.2%), followed by containers (15.6%) and then tankers (9.5%). For the future fleet the majority of vessels remain bulk carriers (50.5%) but there is a change in the order with tankers (17.1%) outnumbering containers (14.3%). The percentage of tankers is higher due to the planned expansion of the Kinder Morgan Westridge Marine Terminal as part of the Trans Mountain Project **(15)** in which the number of relatively large tankers (105,000 to 120,000 DWT Aframax ships) are projected to increase from the 40 trips/year in the existing fleet to approximately 408 trips/year in the future. For both the existing and future fleets, the annual number of cruise ship transits represent slightly less than 10 percent of the total fleet.

**Table 4.1: Annual Vessel Frequency**

| ID | TYPE | DESCR. | VESSEL CAPACITY, DWT (TONNES) | ANNUAL NUMBER OF TRIPS (N) | | | | | | EXISTING TOTAL TRIPS | GROWTH FACTOR | FUTURE TOTAL TRIPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | INBOUND | | | OUTBOUND | | | | | |
| | | | | LOADED | BALLASTED | TOTAL | LOADED | BALLASTED | TOTAL | | | |
| 1 | Ship | Bulk Carrier | 210,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 1.28 | 3 |
| 2 | Ship | Bulk Carrier | 205,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 1.28 | 3 |
| 3 | Ship | Bulk Carrier | 185,000 | 0 | 11 | 11 | 0 | 11 | 11 | 22 | 1.28 | 28 |
| 4 | Ship | Bulk Carrier | 180,000 | 1 | 5 | 6 | 3 | 3 | 6 | 12 | 1.28 | 15 |
| 5 | Ship | Bulk Carrier | 175,000 | 0 | 3 | 3 | 2 | 1 | 3 | 6 | 1.28 | 8 |
| 6 | Ship | Bulk Carrier | 170,000 | 1 | 2 | 3 | 0 | 3 | 3 | 6 | 1.28 | 8 |
| 7 | Ship | Bulk Carrier | 165,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 1.28 | 3 |
| 8 | Ship | Bulk Carrier | 155,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 9 | Ship | Bulk Carrier | 150,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 10 | Ship | Tanker | 120,000 | 0 | 10 | 10 | 10 | 0 | 10 | 20 | 10.20 | 204 |
| 11 | Ship | Bulk Carrier | 120,000 | 0 | 3 | 3 | 2 | 1 | 3 | 6 | 1.28 | 8 |
| 12 | Ship | Container | 120,000 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| 13 | Ship | Tanker | 115,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 10.20 | 41 |
| 14 | Ship | Bulk Carrier | 115,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 15 | Ship | Container | 115,000 | 8 | 0 | 8 | 8 | 0 | 8 | 16 | 1.28 | 20 |
| 16 | Ship | Tanker | 110,000 | 0 | 9 | 9 | 9 | 0 | 9 | 18 | 10.20 | 184 |
| 17 | Ship | Bulk Carrier | 110,000 | 0 | 3 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| 18 | Ship | Container | 110,000 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1.28 | 13 |
| 19 | Ship | Tanker | 105,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 10.20 | 20 |
| 20 | Ship | Bulk Carrier | 105,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 1.28 | 3 |
| 21 | Ship | Container | 105,000 | 19 | 0 | 19 | 19 | 0 | 19 | 38 | 1.28 | 49 |
| 22 | Ship | Bulk Carrier | 100,000 | 0 | 8 | 8 | 6 | 2 | 8 | 16 | 1.28 | 20 |
| 23 | Ship | Container | 100,000 | 42 | 0 | 42 | 42 | 0 | 42 | 84 | 1.28 | 108 |
| 24 | Ship | Bulk Carrier | 95,000 | 0 | 20 | 20 | 11 | 9 | 20 | 40 | 1.28 | 51 |

| ID | TYPE | DESCR. | VESSEL CAPACITY, DWT (TONNES) | ANNUAL NUMBER OF TRIPS (N) | | | | | | EXISTING TOTAL TRIPS | GROWTH FACTOR | FUTURE TOTAL TRIPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | INBOUND | | | OUTBOUND | | | | | |
| | | | | LOADED | BALLASTED | TOTAL | LOADED | BALLASTED | TOTAL | | | |
| 25 | Ship | Container | 95,000 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1.28 | 13 |
| 26 | Ship | Bulk Carrier | 90,000 | 3 | 15 | 18 | 9 | 9 | 18 | 36 | 1.28 | 46 |
| 27 | Ship | Bulk Carrier | 85,000 | 26 | 157 | 183 | 118 | 65 | 183 | 366 | 1.28 | 468 |
| 28 | Ship | Container | 85,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 29 | Ship | Bulk Carrier | 80,000 | 32 | 133 | 165 | 116 | 49 | 165 | 330 | 1.28 | 422 |
| 30 | Ship | Container | 80,000 | 37 | 0 | 37 | 37 | 0 | 37 | 74 | 1.28 | 95 |
| 31 | Ship | Tanker | 75,000 | 0 | 7 | 7 | 7 | 0 | 7 | 14 | 1.64 | 23 |
| 32 | Ship | Bulk Carrier | 75,000 | 6 | 50 | 56 | 34 | 22 | 56 | 112 | 1.28 | 143 |
| 33 | Ship | Container | 75,000 | 45 | 0 | 45 | 45 | 0 | 45 | 90 | 1.28 | 115 |
| 34 | Ship | Tanker | 70,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 35 | Ship | Bulk Carrier | 70,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 36 | Ship | Container | 70,000 | 120 | 0 | 120 | 120 | 0 | 120 | 240 | 1.28 | 307 |
| 37 | Ship | Tanker | 65,000 | 0 | 4 | 4 | 4 | 0 | 4 | 8 | 1.64 | 13 |
| 38 | Ship | Bulk Carrier | 65,000 | 55 | 141 | 196 | 137 | 59 | 196 | 392 | 1.28 | 502 |
| 39 | Ship | Container | 65,000 | 33 | 0 | 33 | 33 | 0 | 33 | 66 | 1.28 | 84 |
| 40 | Ship | Bulk Carrier | 60,000 | 50 | 174 | 224 | 179 | 45 | 224 | 448 | 1.28 | 573 |
| 41 | Ship | GC | 60,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 42 | Ship | Container | 60,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 43 | Ship | Tanker | 55,000 | 1 | 8 | 9 | 8 | 1 | 9 | 18 | 1.64 | 30 |
| 44 | Ship | Bulk Carrier | 55,000 | 7 | 33 | 40 | 27 | 13 | 40 | 80 | 1.28 | 102 |
| 45 | Ship | GC | 55,000 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 1.28 | 28 |
| 46 | Ship | Tanker | 50,000 | 14 | 31 | 45 | 31 | 14 | 45 | 90 | 1.64 | 148 |
| 47 | Ship | Bulk Carrier | 50,000 | 6 | 13 | 19 | 14 | 5 | 19 | 38 | 1.28 | 49 |
| 48 | Ship | GC | 50,000 | 24 | 24 | 48 | 24 | 24 | 48 | 96 | 1.28 | 123 |
| 49 | Ship | Container | 50,000 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1.28 | 13 |
| 50 | Ship | Tanker | 45,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 1.64 | 7 |
| 51 | Ship | Bulk Carrier | 45,000 | 0 | 4 | 4 | 4 | 0 | 4 | 8 | 1.28 | 10 |
| 52 | Ship | GC | 45,000 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| 53 | Ship | Tanker | 40,000 | 2 | 19 | 21 | 19 | 2 | 21 | 42 | 1.64 | 69 |
| 54 | Ship | Bulk Carrier | 40,000 | 22 | 79 | 101 | 77 | 24 | 101 | 202 | 1.28 | 259 |
| 55 | Ship | GC | 40,000 | 7 | 26 | 33 | 26 | 7 | 33 | 66 | 1.28 | 84 |
| 56 | Ship | Tanker | 35,000 | 4 | 8 | 12 | 8 | 4 | 12 | 24 | 1.64 | 39 |
| 57 | Ship | Bulk Carrier | 35,000 | 25 | 51 | 76 | 53 | 23 | 76 | 152 | 1.28 | 195 |
| 58 | Ship | GC | 35,000 | 19 | 45 | 64 | 45 | 19 | 64 | 128 | 1.28 | 164 |
| 59 | Ship | Container | 35,000 | 27 | 0 | 27 | 27 | 0 | 27 | 54 | 1.28 | 69 |
| 60 | Ship | Tanker | 30,000 | 1 | 28 | 29 | 28 | 1 | 29 | 58 | 1.64 | 95 |
| 61 | Ship | Bulk Carrier | 30,000 | 9 | 45 | 54 | 40 | 14 | 54 | 108 | 1.28 | 138 |
| 62 | Ship | GC | 30,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 63 | Ship | ATB | 30,000 | 11 | 18 | 29 | 18 | 11 | 29 | 58 | 1.28 | 74 |
| 64 | Ship | Tanker | 25,000 | 1 | 4 | 5 | 4 | 1 | 5 | 10 | 1.64 | 16 |

| ID | TYPE | DESCR. | VESSEL CAPACITY, DWT (TONNES) | ANNUAL NUMBER OF TRIPS (N) | | | | | | EXISTING TOTAL TRIPS | GROWTH FACTOR | FUTURE TOTAL TRIPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | INBOUND | | | OUTBOUND | | | | | |
| | | | | LOADED | BALLASTED | TOTAL | LOADED | BALLASTED | TOTAL | | | |
| 65 | Ship | Bulk Carrier | 25,000 | 1 | 1 | 2 | 1 | 1 | 2 | 4 | 1.28 | 5 |
| 66 | Ship | GC | 25,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 67 | Ship | ATB | 25,000 | 5 | 8 | 13 | 8 | 5 | 13 | 26 | 1.28 | 33 |
| 68 | Ship | Tanker | 20,000 | 38 | 17 | 55 | 17 | 38 | 55 | 110 | 1.64 | 180 |
| 69 | Ship | Bulk Carrier | 20,000 | 41 | 6 | 47 | 8 | 39 | 47 | 94 | 1.28 | 120 |
| 70 | Ship | GC | 20,000 | 6 | 0 | 6 | 6 | 0 | 6 | 12 | 1.28 | 15 |
| 71 | Ship | Tanker | 15,000 | 0 | 4 | 4 | 4 | 0 | 4 | 8 | 1.64 | 13 |
| 72 | Ship | GC | 15,000 | 5 | 6 | 11 | 6 | 5 | 11 | 22 | 1.28 | 28 |
| 73 | Ship | GC | 10,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 74 | Ship | GC | 5,000 | 10 | 0 | 10 | 10 | 0 | 10 | 20 | 1.28 | 26 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 20 | 0 | 20 | 20 | 0 | 20 | 40 | 1.28 | 51 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 75 | 0 | 75 | 75 | 0 | 75 | 150 | 1.28 | 192 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 43 | 0 | 43 | 43 | 0 | 43 | 86 | 1.28 | 110 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 43 | 0 | 43 | 43 | 0 | 43 | 86 | 1.28 | 110 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 10 | 0 | 10 | 10 | 0 | 10 | 20 | 1.28 | 26 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 12 | 0 | 12 | 12 | 0 | 12 | 24 | 1.28 | 31 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 4 | 0 | 4 | 4 | 0 | 4 | 8 | 1.28 | 10 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| | | **Total Trips:** | | **1019** | **1248** | **2267** | **1733** | **534** | **2267** | **4534** | | **6337** |

**Table 4.2: Vessel Fleet Annual Trip Frequency Summary**

| TYPE | EXISTING FLEET ANNUAL NO. TRIPS | EXISTING FLEET PERCENTAGE | FUTURE FLEET ANNUAL NO. TRIPS | FUTURE FLEET PERCENTAGE |
|---|---|---|---|---|
| **Bulk Carriers** | 2,502 | 55.2% | 3,204 | 50.5% |
| **Tankers** | 432 | 9.5% | 1,085 | 17.1% |
| **Containers** | 706 | 15.6% | 904 | 14.3% |
| **General Cargo** | 386 | 8.5% | 494 | 7.8% |
| **ATBs** | 84 | 1.8% | 107 | 1.7% |
| **Cruise Ships** | 424 | 9.4% | 543 | 8.6% |
| **TOTAL** | **4,534** | **100.0%** | **6,337** | **100.0%** |

### 4.3.1 FUTURE FLEET GROWTH FACTORS

The base case scenario was based on present day and then expanded to a 25-year projection of the number of vessels transiting under the bridge. Vessel growth factors associated with tankers, bulk carriers, containers, general cargo, and cruise ships were based on either known expansion projects or forecasted annual increases in the number of transits for each vessel class over the study's planning horizon. Future forecasts were based on research conducted by Seaport Consultants Canada for the PoV as part of the Trans Mountain project **(15)** [Termpol 3.2, Appendix B]. The forecasts by Seaport are in general agreement with traffic and tonnage estimates by the VFPA. A summary of the growth rates and growth factors used in the risk analysis base cases are shown in **Table 4.3**.

**Table 4.3: Summary of Growth Rates and Growth Factors**

| VESSEL TYPE | ANNUAL GROWTH RATE | GROWTH FACTOR (25 YEARS) |
|---|---|---|
| **Aframax Tankers (105,000 – 120,000 DWT)** | N/A | 10.2 |
| **Tankers (15,000 – 75,000 DWT)** | 2.0% | 1.64 |
| **Bulk Carriers, Containers, General Cargo, ATBs** | 1.0% | 1.28 |
| **Cruise Ships** | 1.0% | 1.28 |

Note that, as part of the risk assessment (**Section 7**), sensitivity analyses were conducted to evaluate the effect of varying the growth rates on the estimated annual frequency of bridge collapse due to vessel collision. The growth rate sensitivity scenarios included: (1) one-half of the estimated base case growth; and (2) two times the base case growth.

## 4.4 VESSEL TRANSIT SPEEDS

Vessel transit speeds are an important component of the risk analysis in determining collision impact forces and energies. Using the Code's Method II procedures, typical vessel speeds are developed for vessels transiting the main navigation channel under normal conditions and are then reduced to determine an estimated aberrant vessel impact speed at each specific bridge pier location in the waterway. The vessel impact speed reduction is estimated using a normal distribution based on the pier's distance from the centerline of vessel transit path in the channel, overall channel geometry, and a standard deviation based on the vessel LOA (**Figure 4-5**). At a distance of three standard deviations from the centerline of vessel transit path, aberrant vessel speeds are assumed equal to the design current in the waterway (the vessel is assumed to be drifting with the current). For LGB the design current is 5 knots. For vessels without a tethered tug the standard deviation is set equal to the vessel LOA in accordance with the Code. For vessels with a tethered tug (primarily loaded tankers greater than 40,000 DWT), the standard deviation is a portion of the LOA as determined by the tug safety factor (**Section 6.4.1**).

For the LGB, vessel impact speeds were established for each specific vessel category and loaded or ballasted (light) condition based on the AIS database for Vancouver Harbour. The AIS data allowed for the determination of actual vessel speeds for each ship in the fleet transiting the main channel inbound/outbound at the bridge location. As shown in **Table 4.4**, transit speeds vary between 7 and 10 knots. Inbound speeds are generally lower than outbound speeds as inbound ships are reducing speed entering the harbour in preparation for

docking at a terminal, whereas outbound ships have left their berth and are picking up speed as they head out to sea. The maximum vessel speed at First Narrows is equal to 10 knots based on current practice. For ships with a tethered tug the maximum speed was set equal to 7 knots (applies primarily to loaded tankers greater than 40,000 DWT).

**Table 4.4: Vessel Speeds**

| ID | DESCR. | VESSEL CAPACITY DWT (TONNES) | VESSEL TRANSIT SPEEDS (KNOTS) | | | | VESSEL TRANSIT SPEEDS (M/SEC) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | INBOUND | | OUTBOUND | | INBOUND | | OUTBOUND | |
| | | | LOADED | BALLASTED | LOADED | BALLASTED | LOADED | BALLASTED | LOADED | BALLASTED |
| 1 | Bulk Carrier | 210,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 2 | Bulk Carrier | 205,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 3 | Bulk Carrier | 185,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 4 | Bulk Carrier | 180,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 5 | Bulk Carrier | 175,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 6 | Bulk Carrier | 170,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 7 | Bulk Carrier | 165,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 8 | Bulk Carrier | 155,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 9 | Bulk Carrier | 150,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 10 | Tanker | 120,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 11 | Bulk Carrier | 120,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 12 | Container | 120,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 13 | Tanker | 115,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 14 | Bulk Carrier | 115,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 15 | Container | 115,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 16 | Tanker | 110,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 17 | Bulk Carrier | 110,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 18 | Container | 110,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 19 | Tanker | 105,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 20 | Bulk Carrier | 105,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 21 | Container | 105,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 22 | Bulk Carrier | 100,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 23 | Container | 100,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 24 | Bulk Carrier | 95,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 25 | Container | 95,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 26 | Bulk Carrier | 90,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 27 | Bulk Carrier | 85,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 28 | Container | 85,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 29 | Bulk Carrier | 80,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 30 | Container | 80,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 31 | Tanker | 75,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 32 | Bulk Carrier | 75,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 33 | Container | 75,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 34 | Tanker | 70,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 35 | Bulk Carrier | 70,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 36 | Container | 70,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |

| ID | DESCR. | VESSEL CAPACITY DWT (TONNES) | VESSEL TRANSIT SPEEDS (KNOTS) | | | | VESSEL TRANSIT SPEEDS (M/SEC) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | INBOUND | | OUTBOUND | | INBOUND | | OUTBOUND | |
| | | | LOADED | BALLASTED | LOADED | BALLASTED | LOADED | BALLASTED | LOADED | BALLASTED |
| 37 | Tanker | 65,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 38 | Bulk Carrier | 65,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 39 | Container | 65,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 40 | Bulk Carrier | 60,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 41 | GC | 60,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 42 | Container | 60,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 43 | Tanker | 55,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 44 | Bulk Carrier | 55,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 45 | GC | 55,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 46 | Tanker | 50,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 47 | Bulk Carrier | 50,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 48 | GC | 50,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 49 | Container | 50,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 50 | Tanker | 45,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 51 | Bulk Carrier | 45,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 52 | GC | 45,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 53 | Tanker | 40,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 54 | Bulk Carrier | 40,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 55 | GC | 40,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 56 | Tanker | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 57 | Bulk Carrier | 35,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 58 | GC | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 59 | Container | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 60 | Tanker | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 61 | Bulk Carrier | 30,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 62 | GC | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 63 | ATB | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 64 | Tanker | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 65 | Bulk Carrier | 25,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 66 | GC | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 67 | ATB | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 68 | Tanker | 20,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 69 | Bulk Carrier | 20,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 70 | GC | 20,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 71 | Tanker | 15,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 72 | GC | 15,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 73 | GC | 10,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |

| ID | DESCR. | VESSEL CAPACITY DWT (TONNES) | VESSEL TRANSIT SPEEDS (KNOTS) | | | | VESSEL TRANSIT SPEEDS (M/SEC) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | INBOUND | | OUTBOUND | | INBOUND | | OUTBOUND | |
| | | | LOADED | BALLASTED | LOADED | BALLASTED | LOADED | BALLASTED | LOADED | BALLASTED |
| 74 | GC | 5,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 75 | Cruise Ship (GT=121,900) | 61,410 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 76 | Cruise Ship (GT=113,600) | 53,680 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 77 | Cruise Ship (GT=93,500) | 49,330 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 78 | Cruise Ship (GT=86,300) | 44,490 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 79 | Cruise Ship (GT=78,300) | 35,120 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 80 | Cruise Ship (GT=55,800) | 29,250 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 81 | Cruise Ship (GT=30,300) | 15,810 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 82 | Cruise Ship (GT=11,000) | 7,050 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 83 | Cruise Ship (GT=5,300) | 3,660 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |

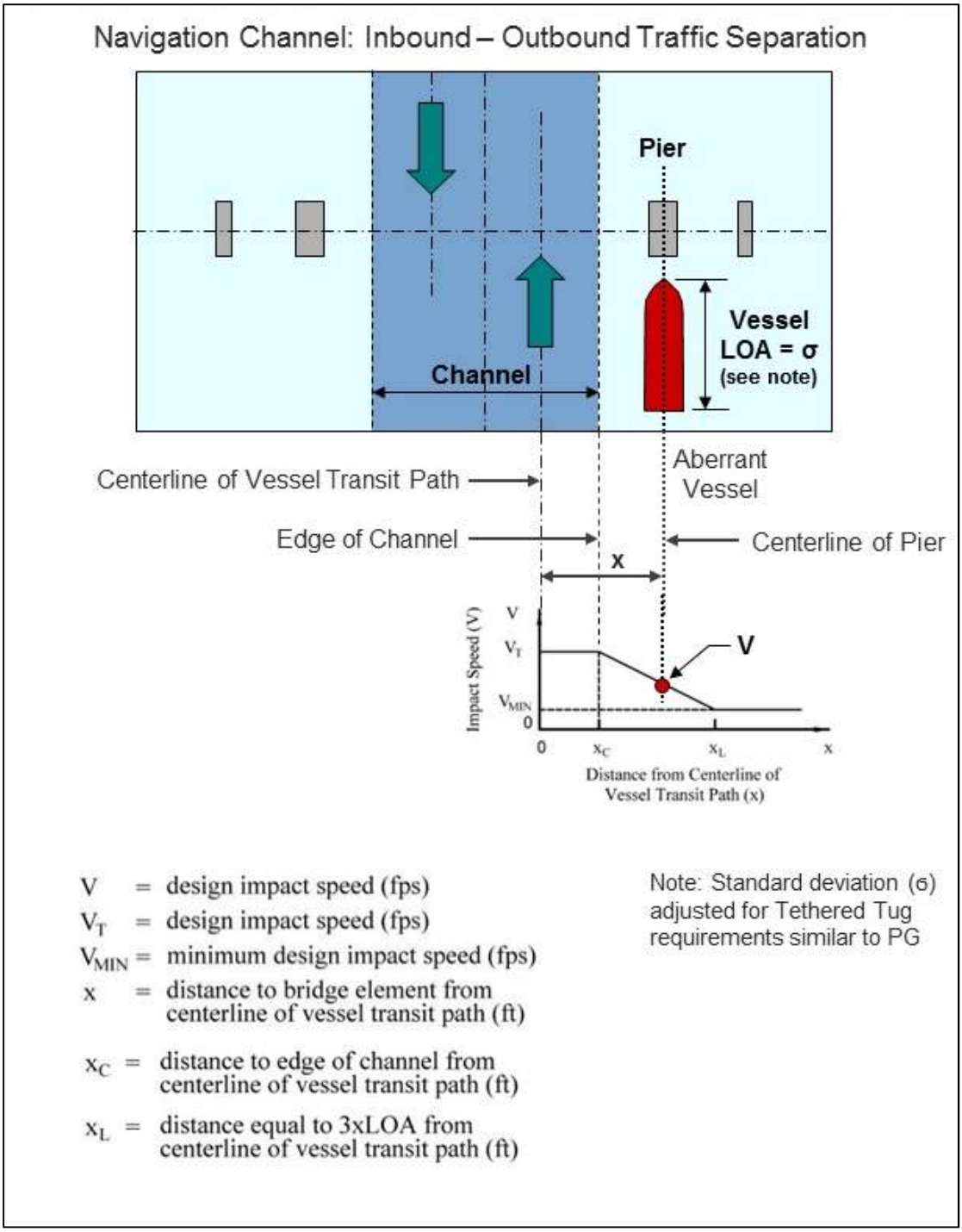



**Figure 4-5: Vessel Speed Distribution**

# 5 VESSEL GROUNDING (SHIP RIDE-UP / PLOUGHING ANALYSIS)

As noted in **Section 3.6**, vessel grounding is an important factor in determining whether an aberrant vessel will reach the LGB towers. On contact with the sea floor, the vessel's kinetic energy will dissipate through a combination of mechanisms:

1. the vessel will rotate and lift as it rides up the slope;
2. the vessel will push into and plough through the sea floor material;
3. the vessel itself will absorb energy through damage to its hull; and
4. hydrodynamic resistance including change in potential energy of water displaced by the vessel as well as wave generation and turbulence will act to resist the vessel's forward motion.

The concept of vessel ride-up and ploughing into a berm are shown in **Figure 5-1**, an excerpt drawn from AASHTO **(5)**. The interaction of all four mechanisms is complex and is a function of numerous geometric and material properties relating to both the sea floor and vessel.

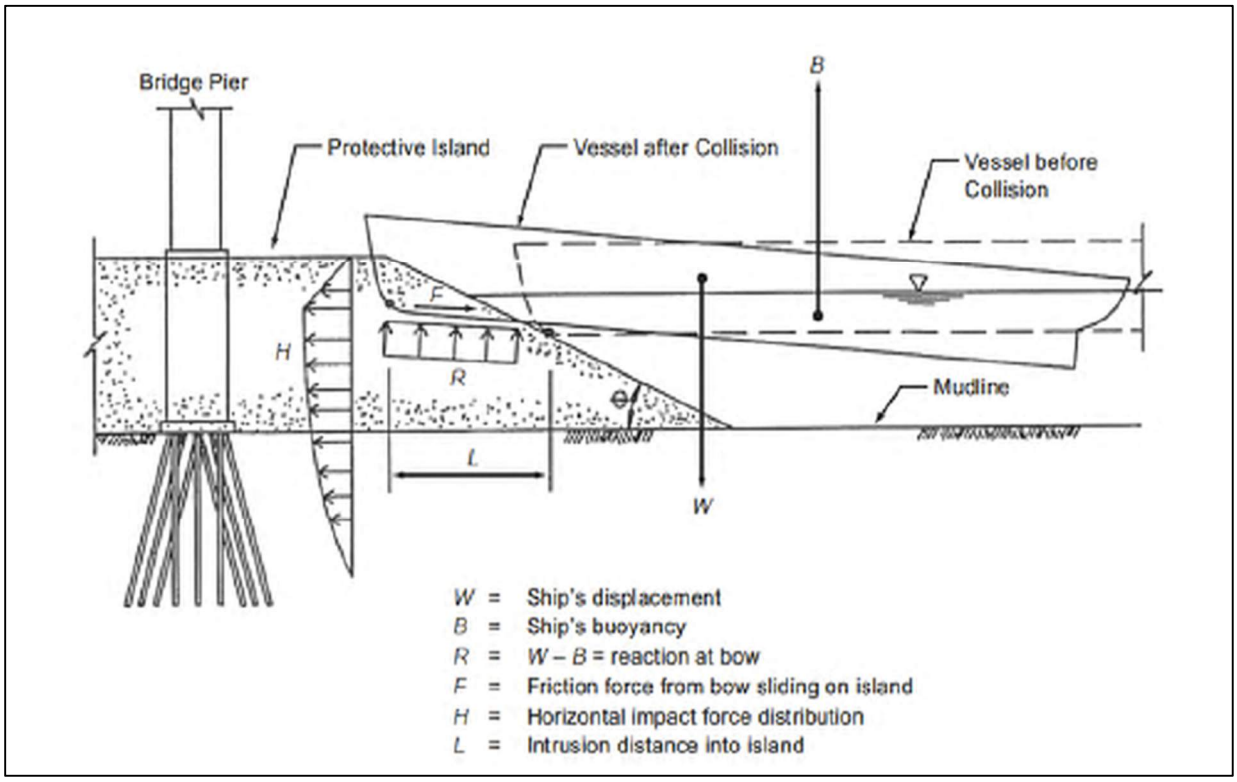



**Figure 5-1: Concept of Vessel Ride-Up and Ploughing (from AASHTO (5))**

For purposes of this study, energy dissipation due to vessel ride-up and ploughing were considered using a detailed "first principles" approach, further described below. For energy dissipation due to vessel damage, a 25% reduction in kinetic energy was applied due to damage of the steel hull of a vessel. For bow encounters with a near-vertical rock slope or the tower base, a 50% reduction was used. These reductions are conservative and consistent with industry practice, including the previous 1984 study **(1)**. With respect to hydrodynamic

effects, the initial kinetic energy was reduced by 14%, consistent with the 1983 recommendation by Fletcher et al **(16)**.

Once completed, the physical interaction models were then integrated into the project's overall risk assessment by making adjustments to the design water depth. For example, where the ploughing / ride up analysis determined that a vessel could not reach the tower (as is the case at the North Tower), then the elevation of the sea floor used in the risk assessment was set equal to zero. By doing so, the vessel collision risk for this structural component will become zero because all vessels are grounded and the number of vessels (N) that could contact the tower is zero.

Alternatively, where a vessel may contact the sea floor but not completely stop before reaching the tower (as is often the case at the South Tower where some vessels slide up the slope a short distance before coming to a stop), the design water depth in the risk analysis was increased to compensate for the vertical ride-up distance which allowed those particular vessels to contact the tower. By doing so, a vessel that rides up the sea floor to such an extent that it could still contact the tower was included in the risk assessment for the bridge. As part of the grounding analysis, the impact force transmitted through the rock berm to the bridge foundation was also evaluated and found to be much less than the structural strength of the concrete pedestal foundation.

## 5.1 NORTH TOWER ANALYSIS

For the North Tower, a ride-up and ploughing model was developed to calculate the horizontal and vertical motion of the bow of the vessel after first contact with the protective berm around the bridge tower, and to calculate the loads imparted on the bridge tower through the rock berm material. Key steps in the analysis were as follows:

The initial kinetic energy of the vessel was calculated as $KE = M(1+c)v^2/2$ where M is the mass of the vessel, c is the added mass coefficient in horizontal translation, and v is the initial velocity. In this analysis, c was set to 0.05.

The numerical model, shown conceptually in **Figure 5-1**, calculated the soil pressures and friction on the sides of the bow, and soil pressure and friction on the keel. The load on the keel results in lifting the bow, and energy is dissipated from lifting the centre of gravity (heave motion) and rotating the vessel as the bow moves up and the stern moves down (pitch motion). For the numerical model, a 60 degree plough, as shown in **Figure 5-2** was applied to the model. This is consistent with the model used for the initial design of the rock berm **(1)**.

The maximum penetration of the vessel into the berm occurs when the energy absorbed is equivalent to the vessel's original kinetic energy, reduced for vessel damage and hydrodynamic resistance. Vertical and horizontal forces acting into the berm are equal in magnitude to, and opposite in direction from, the sum of all reaction forces acting on the vessel.

The numerical model was calibrated using the model tests on the Orwell Bridge as described in AASHTO **(5)** and further reported in Fletcher et al**. (16)**. An illustration of this calibration is shown in **Figure 5-3**. The red line is the numerically modelled track of the first point of contact as the vessel penetrates into the berm, and the green line shows the bow at first contact and when the all of the initial kinetic energy is dissipated, including hydrodynamic added mass. This result matched closely with the ploughing profile (in grey) predicted by Fletcher et al. **(16)**.

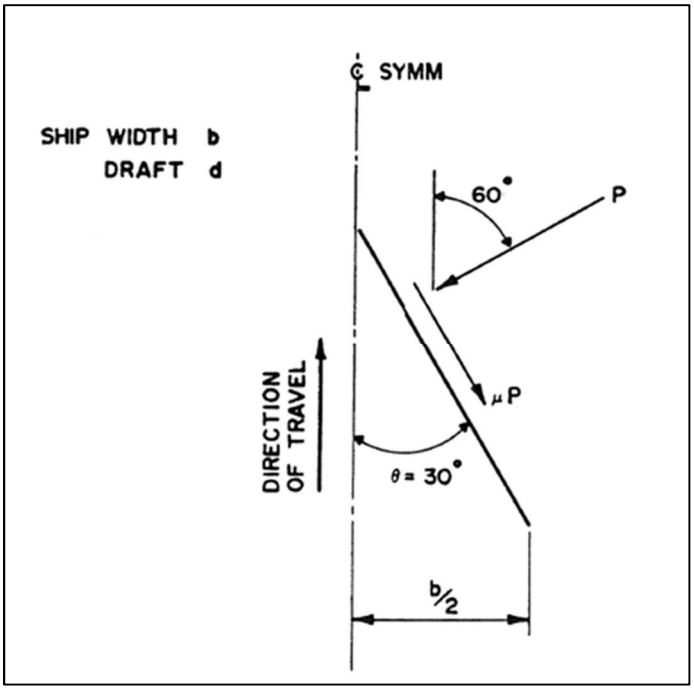



**Figure 5-2: Vessel Ploughing Geometry (1)**

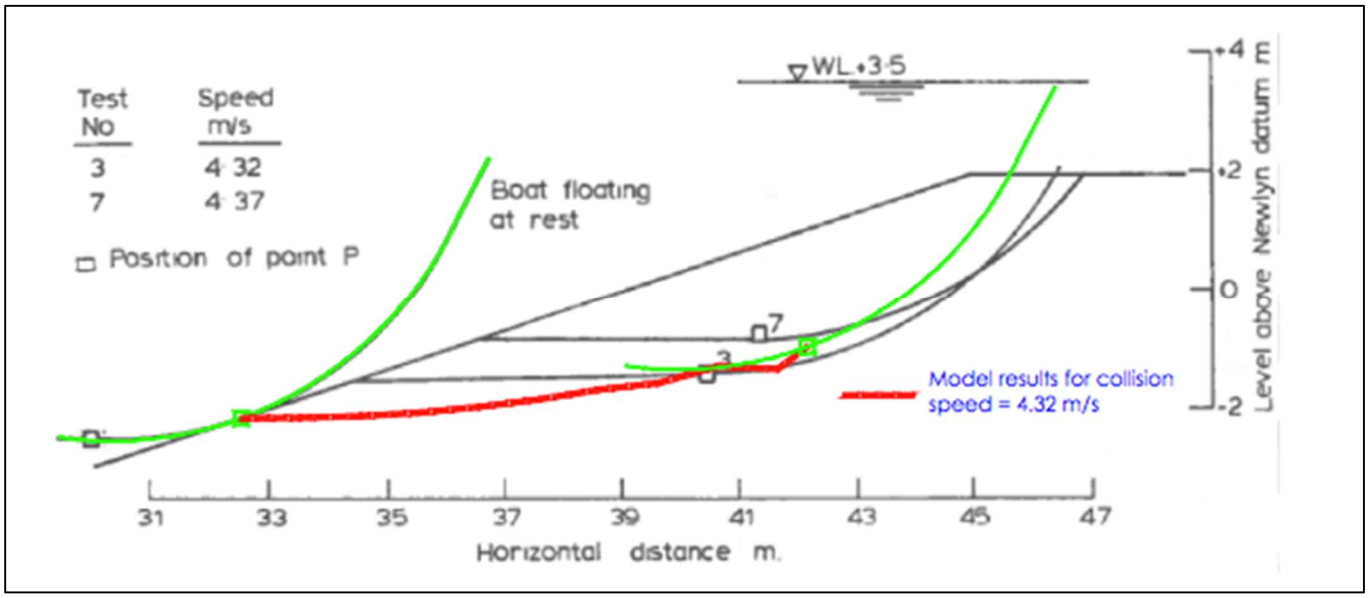



**Figure 5-3: Calibration of Vessel Ride-Up / Ploughing Mechanism**

The numerical model was applied to a range of vessel categories impacting the existing protection berm at four approach angles. Seven "bounded" vessel ride-up / ploughing scenarios are shown in **Appendix B**, and summarized in **Table 5.1**. From this table, it is noted that the minimum bow clearance to the tower legs is governed by relatively shallow draft vessels: (a) cruise vessels with flared bows and; (b) inbound bulkers and tankers that typically enter the harbour in a ballasted configuration.

**Table 5.1: Critical Vessel Ride-Up / Ploughing Scenarios**

| ID | TYPE | VESSEL CAPACITY (DEAD WEIGHT TONNES) | DRAFT CONDITION (M) | | MINIMUM BOW CLEARANCE TO TOWER LEG (M) |
|---|---|---|---|---|---|
| | | | Inbound | Outbound | |
| 1 | Bulker | 210,000 | 5.0 | 15.0 | 21 |
| 35 | Bulker | 70,000 | 3.7 | n/a | 15 |
| 10 | Tanker | 120,000 | 4.7 | 11.9 | 20 |
| 34 | Tanker | 70,000 | 4.2 | 11.0 | 20 |
| 75 | Cruise | 61,410 | 8.3 | 8.3 | 8 |
| 81 | Cruise | 15,810 | 6.1 | 6.1 | 13 |
| 12 | Container | 210,000 | 12.6 | 12.6 | 31 |

This analysis confirmed that the rock berm tower protection system is effective in safely stopping vessels before reaching the North Tower. It was also confirmed that the soil pressures generated during vessel ploughing attenuate through the rock mass and do not have a significant effect on the tower foundation. On this basis, vessel collision risks to the North Tower are considered insignificant and the North Tower was considered as fully protected for the risk analysis.

## 5.2 SOUTH TOWER ANALYSIS

For the South Tower, a ride-up numerical model was developed to calculate the vertical ride-up and horizontal travel of a vessel towards the bridge tower after first contact of the vessel with the rock slope in front of the tower. Because the sea floor is bedrock, only the vessel ride-up mechanism was considered, simplified as shown in **Figure 5-4**; a ploughing mechanism was not considered.

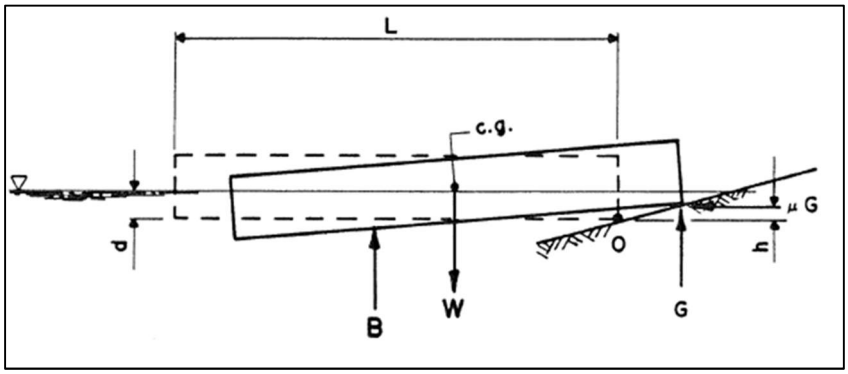



**Figure 5-4: Simplified Vessel Ride-Up Concept (from 1984 Report (1))**

Key steps in the analysis were as follows:

- The initial kinetic energy equation was the same as provided for the North Tower.
- The vertical lift force, G, on the bow of the vessel was calculated for a given vertical movement of the bow. This includes the force to lift the centre of gravity (heave motion) and to rotate the vessel with the bow moving up and stern moving down (pitch motion).
- For a rock slope of angle theta, measured with respect to the horizontal, and a steel-to-rock friction coefficient μ, the horizontal force, H, acting on the bow of the vessel, was determined by taking force

components. For a given vertical lift of the bow, Y, the horizontal distance travelled, X, is calculated as $X=Y/\tan \Theta$.The energy absorbed is calculated as $(X*H + Y*G)/2$.

- This method was adapted to multiple slopes, where the vessel first contacts a flat slope and subsequently contacts a steep slope while still having forward velocity. The analysis of ride-up on the second slope uses the kinetic energy remaining after riding up the first slope.
- The magnitude of final vertical ride-up of the vessel was established when the energy absorbed equals the vessel's initial kinetic energy.

The numerical model was developed for four collision approach angles, variable slopes and roughness, variable friction angles, and ten vessels in loaded and ballasted conditions, and with initial velocities as determined in the risk analysis. Based on the results of the horizontal and vertical ride-up from the analysis, a 2m additional water depth adjustment was selected as a representative value for the risk assessment model. This value was selected predominantly based on the findings of two large vessels: ID #12 Container and ID #75 Cruise Ship, graphically presented in **Appendix B**. These vessel types were identified as critical to the vessel collision analysis since their flared bow and side-bow geometry with large overhangs high above the waterline present the governing hazard to the steel tower legs of the South Tower.

# 6 RISK ASSESSMENT METHODOLOGY

## 6.1 GENERAL

As noted, the vessel collision risk assessment was conducted in accordance with the Method II requirements and procedures of the Canadian Code **(4)**, supplemented by the AASHTO Standards **(5) (6)**.The Code advises that its provisions represent an analytical simplification of a very complex problem. Procedures on how to evaluate typical vessel impacts are provided and illustrated in the Code and general principles are discussed, but it does not explicitly cover every conceivable situation that may be encountered. Therefore, it is left to the designer to use engineering judgement in applying the general analysis principles to model site-specific and sometimes complex navigation channel geometries.

Also note that the Code provisions were initially adopted in 1991 based on accident data and vessel operating procedures and navigation systems in effect prior to the 1990's. As a result, adjustments of the Code's provisions are usually required to model recent advances in navigation technology (such as VTS, AIS, GPS, etc.) as well as site specific situations and restrictions (such as requirements for tethered tugs, multiple pilots, etc.). For the current Lions Gate Bridge study, the magnitude of each adjustment was established based on Code recommendations, published research, and previous risk studies that have been accepted by federal agencies as appropriate for similar marine risk analyses.

The vessel collision risk analysis was conducted based on site specific data related to the First Narrows waterway characteristics, vessel fleet characteristics, and existing bridge characteristics. Data for the analysis was obtained from publicly available sources as referenced in this report. The information in the public domain was also validated with supplemental information and discussions with the VFPA and the PPA.

A variety of sensitivity runs were completed to evaluate the effect of changing some of the key input variables used in the vessel collision risk analysis. These sensitivity checks included variations to the (a) estimated growth rates for the vessel traffic; (b) probability of vessel aberrancy accident base rate; (c) South Tower water depth; and (d) planning horizon for the bridge.

In accordance with the Code, the primary area of interest for aberrant vessels near a bridge is a distance of 2,000m on each side of the crossing. It is assumed that aberrant vessels outside of the 2,000m limit will stop (e.g. the vessel has turned away, dropped anchor, or is drifting at the waterway current speed) prior to impacting the bridge. Within this distance the bridge is located in a straight, transition, or turn waterway region as defined by the Code. The inbound and outbound vessel transit paths and channel geometry within the 2,000m distance is modeled in the risk analysis using a series of tangents, called "legs" to represent bends and to define the straight, transition, or turn waterway regions.

**Figure 6-1** shows the various legs used in the LGB risk assessment. The inbound vessel transit path and channel is divided into four legs (Leg 1, 2, 3 & 4) and the outbound direction is divided into two legs (Legs 5 & 6). The length and angles of each leg varies depending on the channel alignment and bridge location region. The risk analysis is computed for each leg and each direction for each bridge tower. The sum of Legs 1, 2, 3 and 4 represent the inbound vessel risk and the sum of Legs 5 and 6 represent the outbound vessel risk for each tower. The sum of the risks for the towers in each direction represents the risk for the respective inbound and outbound directions. The sum of the inbound and outbound risks represents the total bridge risk.

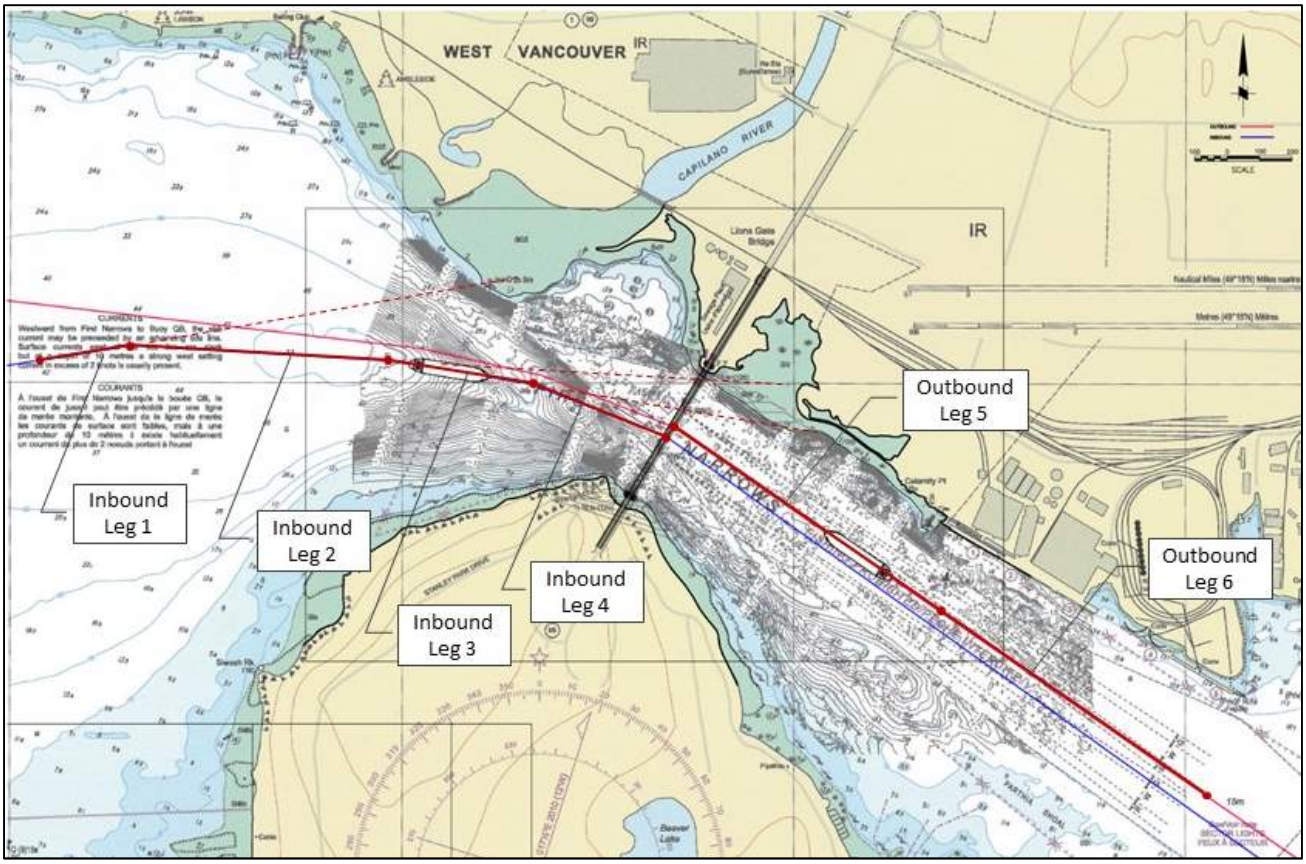



**Figure 6-1: Inbound & Outbound Channel Legs**

As introduced in **Section 1.3.2**, the basic risk equation can be shown as:

$$AFC = (N)\ (PA)\ (PG)\ (PC)\ (PF)\ (GF) \quad \text{(Eq. 1)}$$

A brief discussion of the key risk components as developed for the Lions Gate risk assessment is provided below.

## 6.2 VESSEL FREQUENCY (N)

The annual number of vessels (N) that could potentially strike a bridge element (pier or span) is based on the available water depth and the actual draft of the aberrant vessel. Vessels transiting with drafts deeper than the available water depth will run aground before contacting the piers, while those with drafts less than the available water depths can reach the towers. The vessel fleet and annual frequencies (N) were previously discussed in **Section 4.3** and are shown in **Table 4.1**.

## 6.3 PROBABILITY OF ABERRANCY (PA)

The probability of aberrancy (PA) is a measure of risk that a vessel is in trouble and may stray off-course due to human error, mechanical failure, or adverse environmental conditions. A multi-year study by the American Bureau of Shipping (ABS) reported that human error is the dominant factor in maritime accidents **(17)**. Human error can be attributed to the vessel master, crew, or local pilot onboard the ship. Among all the human error

types classified in the numerous databases and libraries of accident reports evaluated in the ABS study, human failures in situational awareness and situational assessment overwhelmingly predominate. According to accident data from the Canadian Transportation Safety Board (TSB Canada) evaluated in the ABS study, 84% of maritime accidents are directly associated with the occurrence of human error. This is consistent with the findings in other countries; 85% in Australia; 82% in United Kingdom; and 75%-96% by various studies in the U.S.

As documented by TSB Canada annual statistical summaries of marine incidents and a number of studies **(15) (17)**, the trend over the past three decades is one of steady decline in marine accidents leading to loss of property, life, and environmental damage. However, the magnitude of damage inflicted by a major shipping accident increases public attention to those accidents, and negatively influences the perceived safety of shipping **(17)**.

The Code provides a procedure to estimate PA that was calibrated based on historical ship collision accidents with bridges worldwide. The simplified relationships in the Code are used to estimate complex risk components. For purposes of this risk assessment, the Code procedure and accident base rate (BR) values were adjusted (described in the next section) to model the effect of modern ship navigation systems and waterway restrictions that apply to certain vessel types and locations in Vancouver Harbour.

### 6.3.1 SHIP ACCIDENT BASE RATE ADJUSTMENTS (BR)

PA is estimated based on the following equation using an accident base rate (BR), which is then modified for certain waterway and bridge location situations.

$$PA = BR \times RB \times RC \times RXC \times RD \quad \text{(Eq. 2)}$$

where:

- BR = Aberrancy base rate (assumed 0.6 x 10-4 for ships and 1.2 x 10-4 for barges);
- RB = Correction factor for bridge location;
- RC = Correction factor for currents acting parallel to vessel transit path;
- RXC = Correction factor for cross current acting perpendicular to vessel transit path; and
- RD = Correction factor for vessel traffic density.

The aberrancy base rate (BR) for ships assumes that the bridge is located in a coastal area with a requirement for a local pilot to be on-board every vessel. As a result of the pilotage requirement, the base rate for ships is estimated at one-half of the accident base rate for barges. The Code PA base rate also assumes that vessels are transiting with no tug assistance (either escort or tethered tugs).

### 6.3.2 CODE BASE ADJUSTMENTS TO PA

The Code correction factor for bridge location, RB, is based on the relative location of the bridge to one of three waterway regions (straight, transition, and turn/bend). The bridge location factor is computed for each channel leg in the risk assessment.

The correction factors for currents acting parallel (RC) and cross currents (RXC) acting perpendicular to the vessel transit path are computed for each channel leg in the risk assessment using Code procedures. The typical currents near the bridge are in a direction roughly parallel to the vessel transit paths and cross currents on the vessels are minimal, therefore RXC = 1.0.

The Code correction factor for vessel traffic density (RD) in the immediate vicinity of the bridge is determined by whether the structure is located in a low, medium, or high density shipping area or whether vessels are allowed to meet, pass, or overtake each other near the bridge. In accordance with VFPA TCZ-1 requirements at First Narrows, ships are prohibited from meeting or passing in the vicinity of Lions Gate Bridge, therefore RD = 1.0 for both inbound and outbound vessel traffic.

### 6.3.3 TRAFFIC CONTROL ZONES AND MODERN NAVIGATION ADJUSTMENTS

As previously discussed, the Code assumes a single local pilot onboard ships transiting bridges in coastal locations and no tug assistance. The existing Code provisions do not include consideration of new safety measures based on modern navigation systems, vessel design, and regulatory requirements (crew training and certifications, vessel safety inspections, maneuvering restrictions, etc.) that have occurred since the Code's original adoption of AASHTO's vessel collision design provisions published in 1991 (over 25 years ago). The Code also does not provide guidelines for modeling additional navigation restrictions imposed by the TCZ areas in Vancouver Harbour, such as requirements for certain vessels to have multiple pilots, tethered tugs, daylight transits only, and visibility restrictions.

Modern improvements to navigation systems and the TCZ restrictions in the harbour should have the intended consequence of reducing the risk of human error in potential ship collisions with existing bridges. The use of tethered tugs should have the consequence of reducing the drift of aberrant ships in the channel and waterway.

For the LGB risk assessment it was important to include the effects of the above factors in potentially reducing the risk of collision. The base rate in the LGB risk assessment was adjusted to reflect site-specific vessel operating practices in First Narrows in accordance with existing requirements by the VFPA. Adjustments to the aberrancy base rate depended on the size, type and loading condition of the transiting vessels and considered the number of pilots, vessel maneuverability, tug escort, water currents, traffic density, daylight / visibility restrictions, electronic navigation tools and port state control. The magnitude of each adjustment was established based on Code recommendations, published research, and previous risk studies that have been accepted by federal agencies as appropriate for similar marine risk analyses. Key sources of information for adjustments used in the study include:

- IABSE Publication SE-4 "Ship Collision with Bridges" **(18)**; and
- Det Norske Veritas (DNV) Report on "Effectiveness of Risk Reduction Options", Termpol 3.15, Appendix 4, Trans Mountain Project **(15)**.

The potential variability of the PA adjustments was captured through sensitivity analyses. A summary of the PA adjustment factors used in the analysis is shown in **Table 6.1**. The PA adjustments were estimated for each channel leg and for each bridge component in the risk assessment as applicable for the vessel category and ship loading condition (loaded and ballasted). The adjustments and PA aberrancy rate computations for the Base Case (Future Vessel Traffic) vessel categories are provided in **Appendix A**.

**Table 6.1: PA Adjustment Factors**

| ITEM / DESCRIPTON | FACTOR USED IN THE STUDY | DISCUSSION / SOURCE |
|---|---|---|
| Vessel Traffic Service (VTS) | 0.80 | 20% reduction in risk attributed to VTS system and mandatory vessel participation in Vancouver Harbour **(15)**. |
| Electronic Chart Display and Information System (ECDIS) | 0.81 | Compliance with international ECDIS requirements are mandatory for all ships by July 2018 (most vessels calling on ports in Canada and the U.S. are already in compliance). The adjustment is based on 1/2 of the 38% reduction attributed to ECDIS **(15)** because of the overlap with the reduction due to pilots onboard the vessel. |
| Other Navigation Aids | 1.00 | Additional potential risk reductions **(15)** include: AIS (2-5%); ENC (0-13%); Conventional ATNs (0-13%); DGPS (0-8%); and PPU (0-10%). For purposes of this vessel collision risk analysis, these potential reduction factors were conservatively not included. |
| Port State Control (PSC) | 0.94 | PSC includes the inspection of foreign ships to verify compliance with international regulations on the condition of the ship, equipment, crew manning and operations (including rest periods). Studies have demonstrated that PSC activities reduce the rate of vessel accidents in waterways. The adjustment is based on 1/2 of the 12% reduction attributed to PSC **(15)** because of the overlap with the reduction due to pilots onboard the vessel. |
| Pilotage - 1 Pilot | 1.00 | The code base rate assumes a single pilot, therefore a further reduction is not applicable. |
| Pilotage - 2 Pilots | 0.54 | 46% reduction in risk attributed to a second pilot onboard the vessel **(15)**. |
| Passenger / Cruise Ships | 0.17 | Value based on **(18)** [Section 5.2 "Causation Probability - Vessel Type"] which states that vessel accident studies in Japanese waters indicate that passenger vessels are 6 times safer than cargo ships and tankers (which implies a 83% reduction in risk, or a reduction factor of 0.17). |

## 6.4 GEOMETRIC PROBABILITY

The geometric probability (PG) is the conditional probability that a vessel will hit a bridge component (pier or span) given that it has lost control (i.e. it is aberrant) in the vicinity of the bridge. The Code method of computing PG is based on a standard normal distribution curve ($\phi$), with the mean located at the centerline of vessel transit path and a standard deviation ( $\sigma$ ) equal to the length overall (LOA) of the vessel category under consideration. Bridge elements located beyond three (3) standard deviations from the centerline of vessel transit path do not influence the geometric probability of collision. The area under the normal distribution curve bounded by the limits of the centerline of vessel contacting either side of the pier is equal to the geometric probability of collision (**Figure 6-2**).

For this study, the distance between the centerline of bridge element relative to the centerline of all vessel transit paths (Legs 1, 2, 3 and 4 inbound and Legs 5 and 6 outbound) was determined and used to compute PG for each vessel category at all pier locations (**Appendix A**). **Figure 6-3** illustrates how the PG normal distribution was applied to each channel leg at the bridge location.

The standard deviation used to compute PG was adjusted for loaded tankers equal to or larger than 40,000 DWT, transiting with tethered tugs.

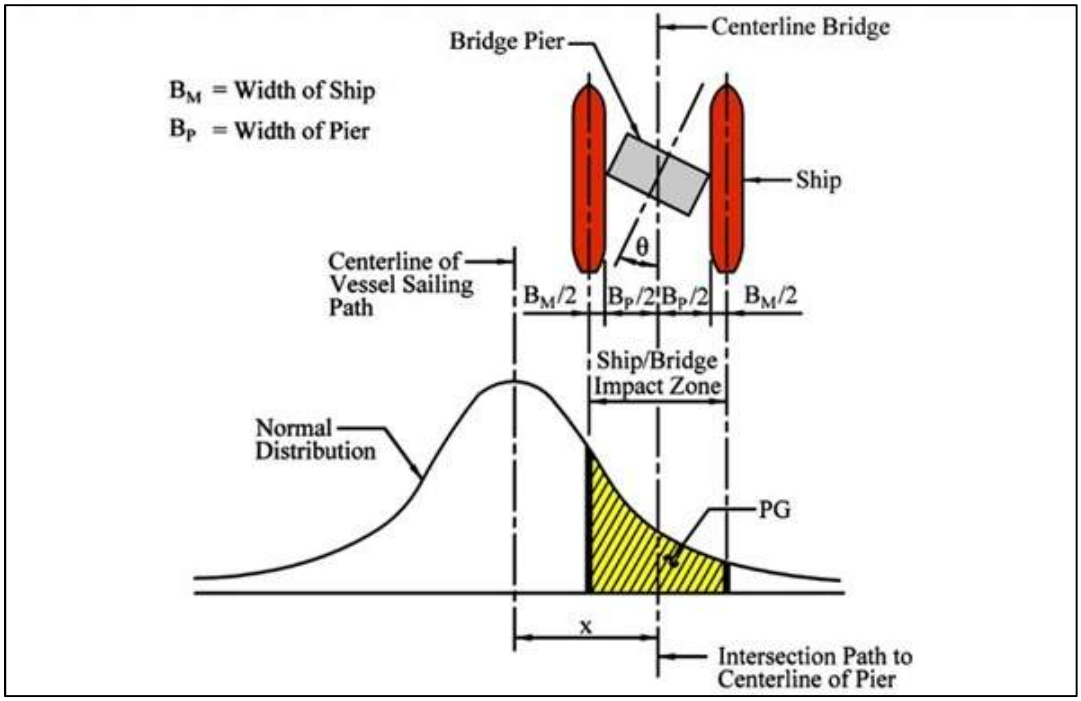



**Figure 6-2: Geometric Probability PG (5)**

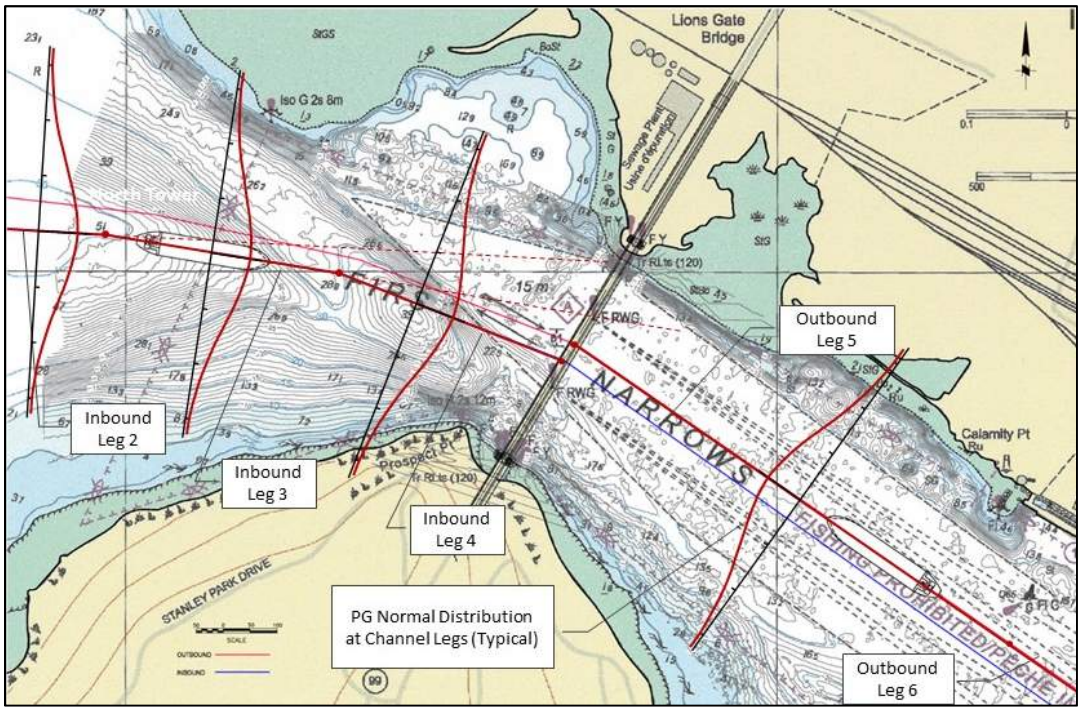



**Figure 6-3: PG Normal Distribution Plan**

## 6.4.1 ADJUSTMENT FOR TETHERED TUGS

Tug assistance during vessel transits provide an extra measure of security related to potential vessel collision as tugs assist in keeping an aberrant vessel in the navigation channel. The VFPA and PPA have undertaken

several studies using ship simulators and actual in-water tests in Vancouver Harbour to validate the TCZ tug procedures and requirements **(10)**. For purposes of this risk assessment study only tugs tethered to the vessel in accordance with VFPA's TCZ criteria (which defines the size and number of tugs based on ship DWT) are considered. Because of potential time delays in hooking up with a vessel near the bridge location, escort tugs and tugs of opportunity were excluded from this risk assessment.

Within the context of the Code procedures for estimating the risk of vessel collision, the use of tugs may have a slight benefit in reducing the PA base rate (minor because the major cause of aberrancy is human error onboard the ship). The primary benefit will be to the PG factor in reducing the ability of an aberrant vessel to leave the navigation channel as the tugs can push the vessel back into the channel and keep it away from the bridge. The following equation was developed as part of this risk assessment to model the effect of tethered tugs on PG by introducing an adjustment factor ($r_{tug}$) to reduce the standard deviation ( $\sigma$ ) based on a tug safety factor ($f_{tug}$), width of the channel (w), vessel LOA and properties of a standard normal distribution ($\phi$).

$$r_{tug} = \frac{0.5w}{loa\Phi^{-1}\left(1 - \frac{1 - \Phi\left(\frac{0.5w}{loa}\right)}{f_{tug}}\right)}$$

A tug safety factor ($f_{tug}$) of 2.0 was selected for the risk assessment base cases following the data in **(15)** and other ship navigation studies. Although the tug adjustment factor ($r_{tug}$) varies based on vessel size, the typical reduction factor for the ships in the vessel fleet at Lions Gate Bridge is an adjusted standard deviation of approximately 1/3 of LOA (0.33). The effect of the adjustment to PG is shown in **Figure 6-4**. The use of a reduced standard deviation causes the spread of the normal distribution to "peak" closer to the mean (channel centerline). This reduces the PG associated with bridge piers when compared to PG estimates without the adjustment.

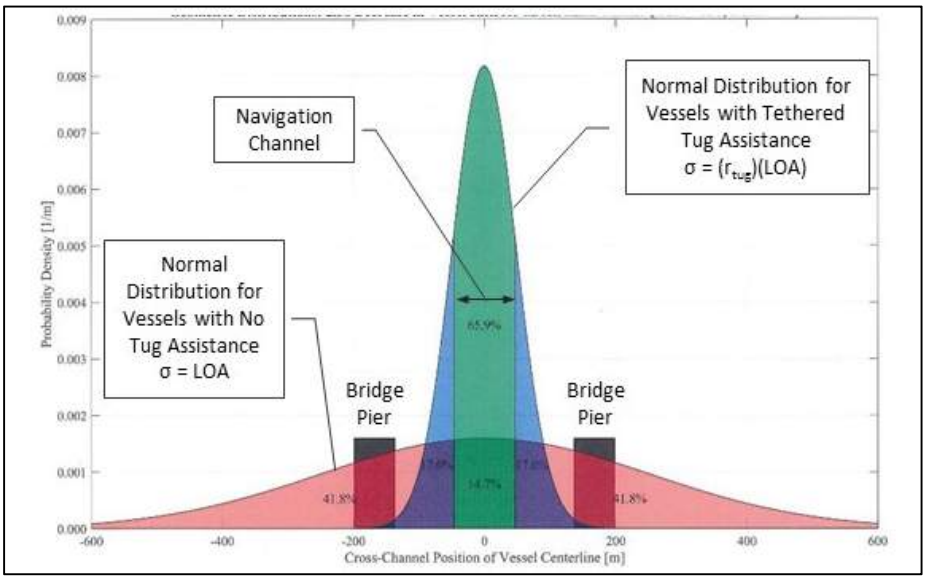



**Figure 6-4: PG Tug Adjustment Factor**

Note that this methodology to account for tethered tugs was developed for use in both the current study of Lions Gate Bridge and a parallel study for Ironworkers Memorial Bridge. As was subsequently learned through the course of this study, the current impact of tethered tugs is relatively small at Lions Gate Bridge. This is because the current TCZ rules for First Narrows only call for tethered tugs for loaded tankers equal to or larger than 40,000 DWT, or very large bulk and container ships, a relatively small number compared to the total vessel transits at First Narrows.

It should also be noted that the adjustment in the standard deviation used to estimate PG for vessels with tethered tugs are also made to the standard deviation used in the vessel speed distribution previously discussed in **Section 4.4**.

## 6.5 PROBABILITY OF COLLAPSE (PC)

The probability of bridge collapse (PC) once an aberrant vessel has struck a pier or bridge component is a function of many variables including vessel size, type, bow shape, speed, direction of impact, mass, and dynamic response of both the vessel and the bridge. It is also dependent upon the ability of the tower to resist collision impact loads. Based on historical accident data and ship collision research, the probability of collapse in the Code is estimated based on the ratio of bridge element ultimate strength (H) to the vessel impact forced (P) as illustrated in **Figure 6-5**.

Code relationships based on vessel size and impact speeds were used in the risk assessment to estimate impact loads (forces and energies) associated with vessel collision. In accordance with the Code, the full bow impact force was applied at the waterline to compute PC for tankers and bulk carriers impacting the concrete pedestal of the tower. For containers, general cargo and cruise ships with relatively large flared bows, vessel impacts can occur with the steel tower legs high above the water. For impacts with the flared bow, the vessel impact force was conservatively taken as one-half the full bow impact load (the Code requires that the full impact force be distributed along the depth of the bow to evaluate local collision forces). As noted previously, the resistance strength of the steel tower legs was assumed to be zero for impacts by flared bows, therefore the PC would be 100 percent for those type of impacts (PC = 1.0).

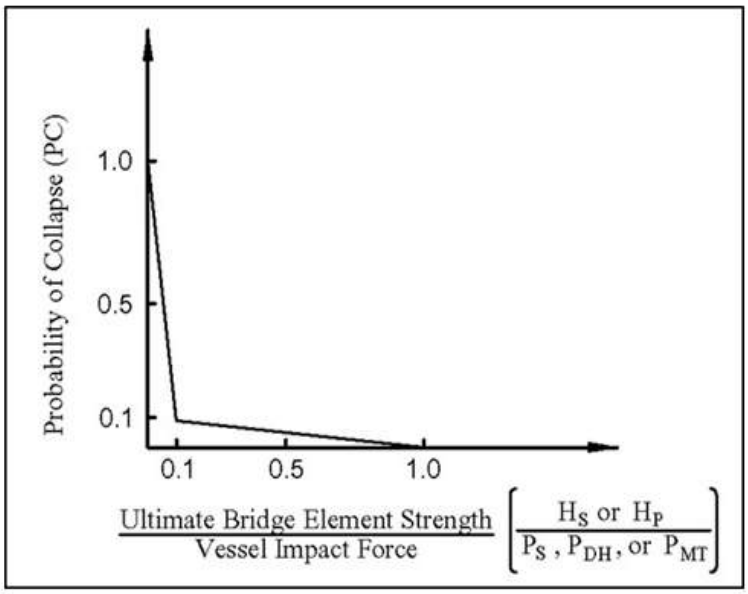



**Figure 6-5: Probability of Collapse (5)**

## 6.6 VESSEL COLLISION ANGLES & PROTECTION FACTORS (PF)

The protection factor (PF) is used to model protection provided by upstream and/or downstream land masses (or other waterfront structures) adjacent to the bridge that would block an aberrant vessel from striking a bridge element, regardless of the actual water depth. The procedure used to compute the protection factor was

based on the AASHTO **(5)** methodology for estimating the reduction in annual frequency of collapse due to pier protection structures, such as large diameter dolphins. The procedure is similar to the geometric probability. PF is based on a normal distribution curve, with the mean located at the centerline of assumed vessel transit path and a standard deviation equal to 30 degrees of rotation from the transit path. The location of adjacent land masses or protection structures with respect to the bridge are used to develop potential "collision angles" which are then used to estimate PF.

The collision angles for LGB were based on typical ship turning diameters in conjunction with the land masses and bathymetry near the North and South Towers. In accordance with International Maritime Organization (IMO) requirements, ships are designed for emergency turns at maximum rudder angle (usually 35°) in which the ship must make a turning circle with a tactical diameter of less than 5xLOA and an advance course less than 4.5xLOA (**Figure 6-6**). As illustrated in **Figure 6-7**, transit paths based on ship turning circles representing potential aberrant ship movements were plotted along each channel leg for each pier to determine collision angles and associated protection factors. A summary of the collision angles are shown in **Figure 6-8** and a tabulation of the protection factors are included in **Appendix A** for each leg in the risk assessment.

The protection factors developed for the South Tower indicated that its primary exposure is from outbound vessels (Legs 5 and 6). The South Tower has minimal collision exposure from inbound vessels (Legs 1, 2, 3 and 4) because of its location inside the inbound turn in the channel and because of its partial protection inside a small cove with shallow water depths. Protection factors for the North Tower indicated (theoretical) collision exposure from inbound vessels because of its location outside the inbound turn and some exposure to outbound vessels.

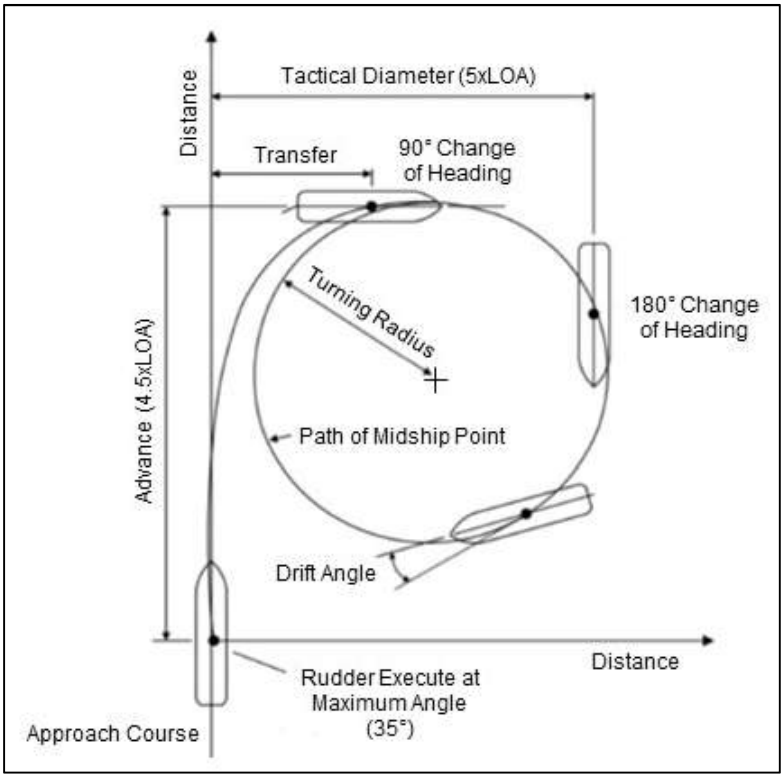



**Figure 6-6: Ship Turning Circles**

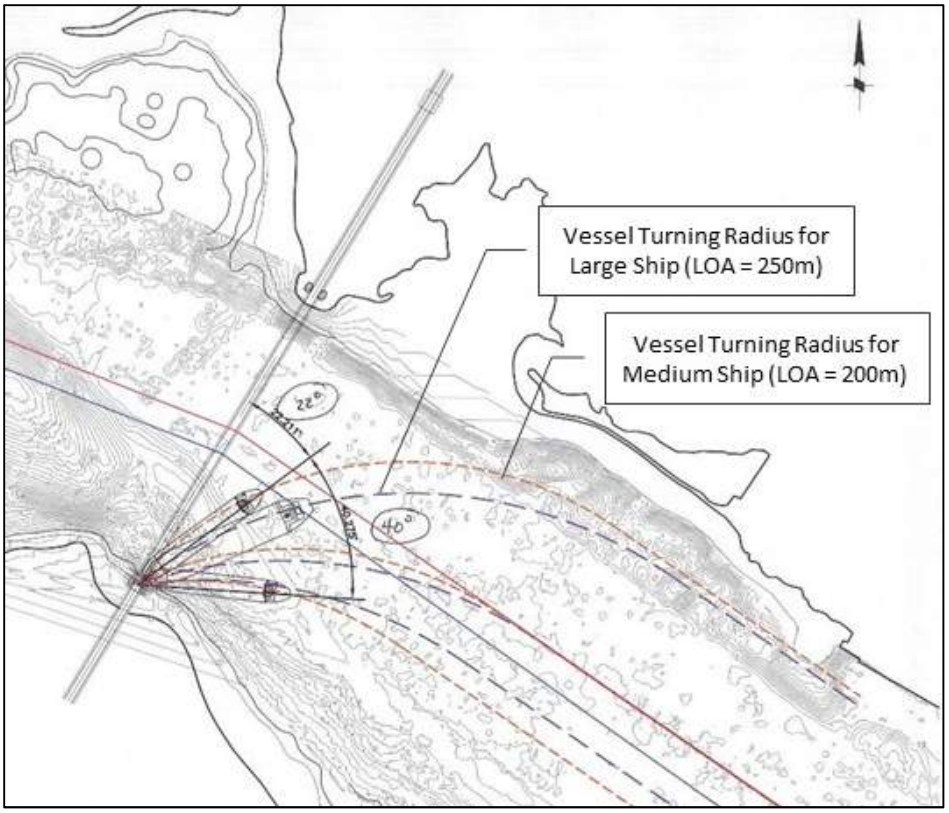



**Figure 6-7: Outbound South Tower Collision Angles**

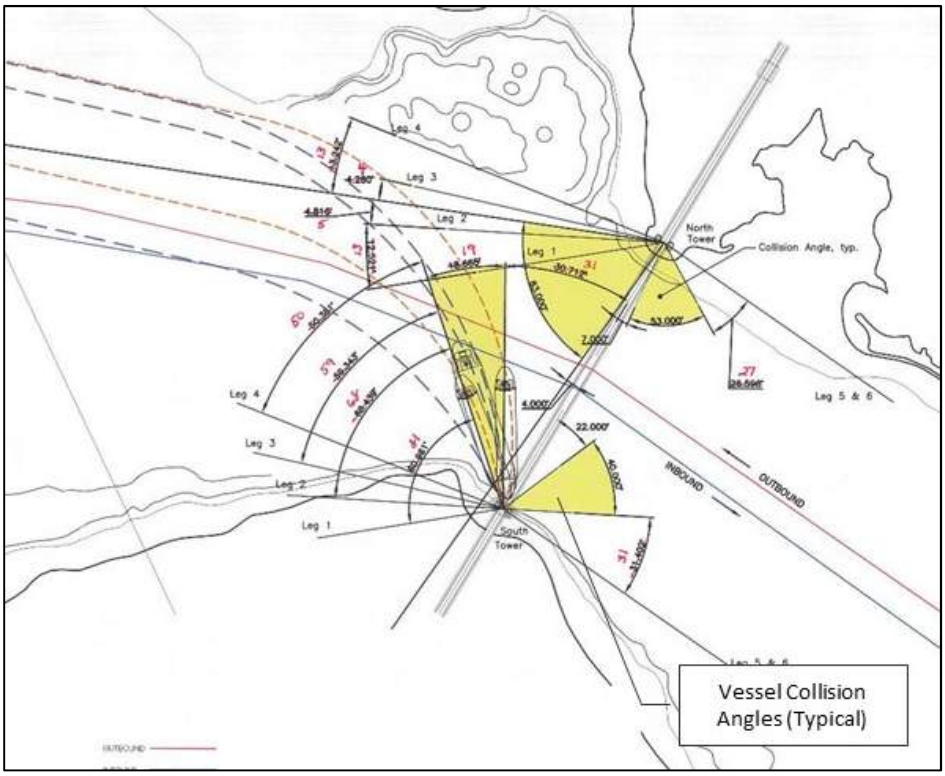



**Figure 6-8: Summary of Collision Angles**

# 7 RISK ASSESSMENT RESULTS

## 7.1 BASE CASE SCENARIOS

Results of the base case risk analyses are summarized in **Table 7.1. Appendix A** provides details of the input and vessel collision analysis files for the Future Vessel Traffic (25 Year Projection) Base Case.

**Table 7.1: AFC Summary**

| BASE CASE | ANNUAL FREQUENCY OF COLLAPSE (AFC) Return Period (Years) (10,000 Years is Threshold for Class I Bridge) | | |
|---|---|---|---|
| | Inbound Vessels | Outbound Vessels | Total |
| **Present Day Vessel Traffic** | 29,146 | 6,383 | **5,236** |
| **Future Vessel Traffic (25 Year Horizon)** | 22,770 | 4,986 | **4,091** |

## 7.2 SENSITIVITY SCENARIOS

Factors used in a vessel collision risk study are intended to best reflect the reality of a bridge site, waterway and fleet characteristics. Nonetheless, each of the factors has an unavoidable degree of uncertainty. To gauge the significance of an uncertainty, a sensitivity analysis can be run where the factor is changed and its influence on the overall conclusion is evaluated.

Each of the factors used in the current study reflect the best estimate of reality based on relevant Codes, published research and previous risk studies that have been accepted by federal agencies for similar marine risk analyses. Several sensitivity runs were completed to evaluate the effect of varying key input variables. These sensitivity checks included variations to the (a) estimated growth rates for the vessel traffic; (b) probability of vessel aberrancy accident base rate; (c) South Tower water depth; and (d) planning horizon for the bridge. Note that all sensitivity analyses used the 25-year horizon for future vessel traffic as the Base Case for comparison.

### *7.2.1 GROWTH RATE SENSITIVITY*

If the estimated growth rate was cut in half (50%) of that anticipated, the total bridge AFC return period would increase from 4,091 to 4,634 years.

If the estimated growth rate was doubled (2 times) of that anticipated, the total bridge AFC return period would decrease from 4,091 to 3,193 years. In this scenario the number of vessels for the Kinder Morgan project were capped at 408 trips/year and all other vessel categories were increased at twice the base rate growth.

### 7.2.2 PROBABILITY OF ABERRANCY SENSITIVITY (PA)

If the probability of aberrancy base rate (BR) was cut in half (50%) of that anticipated, the total bridge AFC return period would increase from 4,091 to 8,181 years. This represents an outcome if the assumed BR adjustment factors were overly conservative. For example, discussions with the VFPA and PPA indicate that the use of the portable PPU units carried by the pilots onboard each vessel provide a significant amount of navigation information and are being modified to receive real-time data of tides, currents and winds from measuring stations in the harbour (one is near the Lions Gate Bridge). In the present study, no reduction in risk was (conservatively) attributed to the use of PPU units.

If the probability of aberrancy base rate (BR) was increased 1.5 times of that anticipated, the total bridge AFC return period would decrease from 4,091 to 2,727 years. This (and the following BR increases) would represent an outcome if the assumed BR adjustment factors were not adequately conservative and the BR rates should be higher. If the probability of aberrancy base rate (BR) was increased 2.0 times of that anticipated, the total bridge AFC return period would decrease from 4,091 to 2,045 years.

### 7.2.3 SOUTH TOWER WATER DEPTH SENSITIVITY

The sea floor at the South Tower is rock with an existing elevation of El -7.0m near the tower (rock elevations range from El -1.0 to -7.0 chart datum adjacent to the concrete pedestal). A sensitivity analysis was conducted to see the effect of raising the elevation near the tower through some type of underwater berm or island similar to the existing protection rock berm at the North Tower. By raising the rock to an elevation of El -4.0m or higher, the total bridge AFC return period exceeds 13,300 years. This is due to aberrant vessels with deeper drafts running aground as a result of shallower water depths near the tower.

### 7.2.4 PLANNING HORIZON SENSITIVITY

In 2000-2001, the bridge was extensively retrofitted including seismic upgrades and an outright deck replacement, extending the remaining expected service life of the bridge to an estimated 100 years. If the 50-year study horizon used in the base case risk assessments was increased to 100 years, the total bridge AFC return period would decrease from 4,091 to 3,036 years.

## 7.3 KEY RISK ANALYSIS FINDINGS

The analysis estimated the AFC due to vessel collision for the Base Case (Present Day Vessel Traffic) has a return period of 5,236 years. The estimated AFC for the Base Case (Future Vessel Traffic) has a return period of 4,091 years. These results indicate that the AFC meets the criteria for a Class II (Regular Importance) highway bridge but does not meet the criteria for a Class I (Critical Importance) highway bridge. Key findings of the risk analysis are summarized as follows:

1. The primary bridge vulnerability is the potential impact of the flared bow of a container, general cargo or cruise ships with the South Tower steel legs. The overhang of the flared bow can contact the tower leg above the tower pedestal before the portion of the ship's bulbous bow below the water makes contact with the concrete pedestal / foundation.
2. The potential vulnerability of the concrete pedestal / foundation is low since the resistance strength of these bridge components is very high. Therefore, the risk of collapse resulting from tankers and bulk carrier impacts (which have blunt bows and contact the South Tower concrete protection collar on the foundation at or below the waterline) is not significant.

3. Over 80% of the collision risks to the bridge are due to outbound vessels. This is because of the South Tower's location inside the inbound turn in the channel and its partial protection inside a small cove with shallow water depths.
4. The North Tower is protected from vessel collision by an existing rock berm island protection system. An analysis of potential vessel grounding and ride-up on the rock berm performed as part of this study confirmed that vessels would be safely stopped before potential contact was made by the flare of ship bows above the water with the tower leg or by the bulbous bow of the ship with the concrete pedestal of the tower.
5. Reducing the water depth at the South Tower from the existing El -7.0m to a revised elevation of El -4.0m (or less) would result in return periods exceeding 10,000 years. This change in risk is related to the larger container, general cargo, and cruise ships, which start to run aground at these depths. A reduction in water depth could be accomplished by an underwater berm or by a protection island similar to the North Tower.

## 7.4 DESIGN VESSELS

Design vessels are determined for each tower by using the risk assessment model to identify the vessel in the fleet (and all other vessels smaller in size) that collectively trigger the acceptance criteria of 1 in 10,000 years for the total bridge. For the Lions Gate Bridge, the North Tower is protected by an existing rock berm, therefore only the South Tower has been evaluated. Since the analysis has four different water levels, each water level has (theoretically) its own design vessel. As a practicable matter however, the largest design vessel would be used to design any type of physical protection system.

A summary of the South Tower design vessels is shown in **Table 7.2** with their associated vessel collision impact loads. As shown in this table the largest design vessel is a loaded 80,000 DWT container ship. The risk assessment indicated that at elevation El -0.1 (which is the lowest low water tide height), the South Tower meets the risk acceptance criteria due to most of the vessel fleet running aground, therefore no design vessel is required for that water level.

Development of a protection system at the South Tower that could withstand the 80,000 DWT container ship impact force and energy would result in an AFC return period of approximately 10,000 years (the actual computed value was 11,439 years). It should be noted that the vessel fleet includes vessels much larger than 80,000 DWT in size, but the smaller number of trips (N) and deeper drafts of the larger vessels result in lower risks at the South Tower and they are within an acceptable risk range (they are cumulatively the vessels representing the 10,000 year criteria).

Based on the risk assessment, it should also be noted that the recommended design vessel was not a large cruise ship. Even though cruise ships represent about 10 percent of the total fleet passing under Lions Gate Bridge, their PA base rate was 1/6 of the rate used for container ships and all other vessel types which resulted in a lower risk for cruise ship collision with the South Tower (the risks would be within the acceptance criteria).

**Table 7.2: South Tower Design Vessels**

| WATER ELEVATION (M) CHART DATUM | VESSEL ID # | VESSEL DESCRIPTION | MAXIMUM IMPACT FORCE, P (MN) | MAXIMUM COLLISION ENERGY, KE (MN-M) | VESSEL IMPACT SPEED, V (M/SEC) |
|---|---|---|---|---|---|
| 5.0 | 30 | 80,000 DWT Container Ship (Loaded) | 156.31 | 1,226.10 | 4.64 |
| 3.3 | 33 | 75,000 DWT Container Ship (Loaded) | 150.91 | 1,186.37 | 4.63 |
| 1.6 | 58 | 35,000 DWT General Cargo Ship (Loaded & Ballasted) | 94.39 | 219.22 | 4.24 |
| -0.1 | N/A | | | | |

*Note: No design vessel is specified for the lowest water elevation since most of the vessel fleet will run aground at that elevation.*

# 8 PHYSICAL MITIGATION: OPTIONS AND SITE CONSIDERATIONS

## 8.1 TYPICAL PHYSICAL MITIGATION OPTIONS

Physical protection measures can be implemented to mitigate the risk of vessel collision. As part of a new bridge, or as an upgrade to an existing structure, physical protection provides a combination of strength resistance, energy absorption and vessel redirection. Physical protection systems are typically grouped into the following categories, listed as follows:

- **Fenders** are structural components mounted to an existing pier and intended to absorb energy through plastic bending, crushing or buckling. They are typically made of timber, rubber, concrete and/or steel and can include both custom-designed and proprietary systems. Fenders are typical used in combination with other systems or intended for "*medium to small vessels at low impact speeds and at oblique angles.*" **(5)**. One such local example is the steel fendering at the Sea Island Bridge in Richmond, BC (**Figure 8-1**).

**Figure 8-1: Steel Fendering at Sea Island Bridge, Richmond BC**

- **Pile-Supported Systems** are structural components that may be attached or independent of the pier it is protecting and can be a suitable option for a wide-range of vessel collision scenarios. They are typically made of timber, concrete and/or steel and are often designed as sacrificial components. One such local example is the timber piling to protect the piers at the Moray Bridge in Richmond, BC **(Figure 8-2)**.

**Figure 8-2: Timber Pile Supported Protection at Moray Bridge, Richmond BC**

- **Dolphins** are standalone components, typically comprised of driven steel sheet piling, filled with rock or concrete and topped with a concrete cap. They are most often circular to facilitate vessel redirection, but are sometimes rectangular when used for mooring. They are typically a sacrificial component in high energy collision scenarios. Fender are often installed on the perimeter of the dolphins. A prominent and often-cited North American bridge example is the dolphins used for the Sunshine Skyway in Tampa Bay, Florida **(Figure 8-3)**.
- **Islands / Berms** are a rock fill embankment built up around a pier to ground the vessel and stop it in advance of contact. Energy dissipation is provided through a combination of (a) vessel rotation / ride-up; (b) hull friction and ploughing into the rock fill: (c) crushing and distortion of the vessel's hull; and (d) hydrodynamic resistance of the vessel through waves and turbulence. Rock fill berms have been used on many of the local bridges including the Alex Fraser Bridge, North Arm Bridge (Skytrain) and the North Tower of Lions Gate Bridge **(Figure 3-1**).
- **Floating Protection** can include cable nets, anchored pontoons and floating booms. They are less common, typically only considered in deep water applications. They typically require a large area to deform and absorb collision energy and are not well suited to narrow channels. There is no floating protection systems installed at the local major bridges.

**Figure 8-3: Dolphin Protection at Sunshine Skyway**

## 8.2 LGB VESSEL COLLISION PROTECTION CONSIDERATIONS

The primary LGB bridge vulnerability is the potential impact of the flared bow of a container, general cargo or cruise ships with the South Tower steel legs at elevations significantly above the water. The tower legs have minimal capacity for vessel impact whereas the supporting concrete pedestal / foundation has very high strength. Any solution to this vulnerability, therefore, is first challenged by the geometry of the collision scenario, and then establishing a viable load path and energy dissipation mechanism.

### *8.2.1 VESSEL COLLISION GEOMETRIC REQUIREMENTS*

The design geometry for potential protection measures is defined in **Figure 8-4** and shows the anticipated vessel approach angles (shaded in yellow) and the proposed outer boundary of a protection structure, 23 m offset from the inside face of the South Tower's protection collar. This 23m offset was established to ensure the flared bow of a vessel does not reach the steel tower leg, allowing for (a) 9m of vessel travel after first point of bow contact / grounding; and (b) 4m (+/-) of clear distance (i.e. safety buffer) from the tip of the vessel's bow to the face of the South Tower leg. Note that this protection boundary offset is based on the largest vessel geometry amongst the entire transiting fleet. On this basis, the suggested concepts achieve a risk reduction that will exceed the 1:10,000 AFC return period criteria. At a future detailed design stage, the Ministry may elect to refine these concepts while reducing the AFC return period but still achieving the 1:10,000 criteria.

The 9m "vessel travel" distance is to account for the complex grounding interaction of the vessel, sea floor and protection structure, and includes vessel rotation and ride-up, vessel ploughing and damage to the vessel hull. Illustrated in **Figure 5-1**, these mechanisms and the analytical approach used for this study are provided in **Section 5**. The interaction for each collision scenario will depend on the vessel characteristics and the protection structure under consideration. For concept development, a conservative 9m design envelope was established based on review of numerous collision scenarios, with particular focus on vessels with a flared flow that present the greatest hazard to the tower's steel legs.

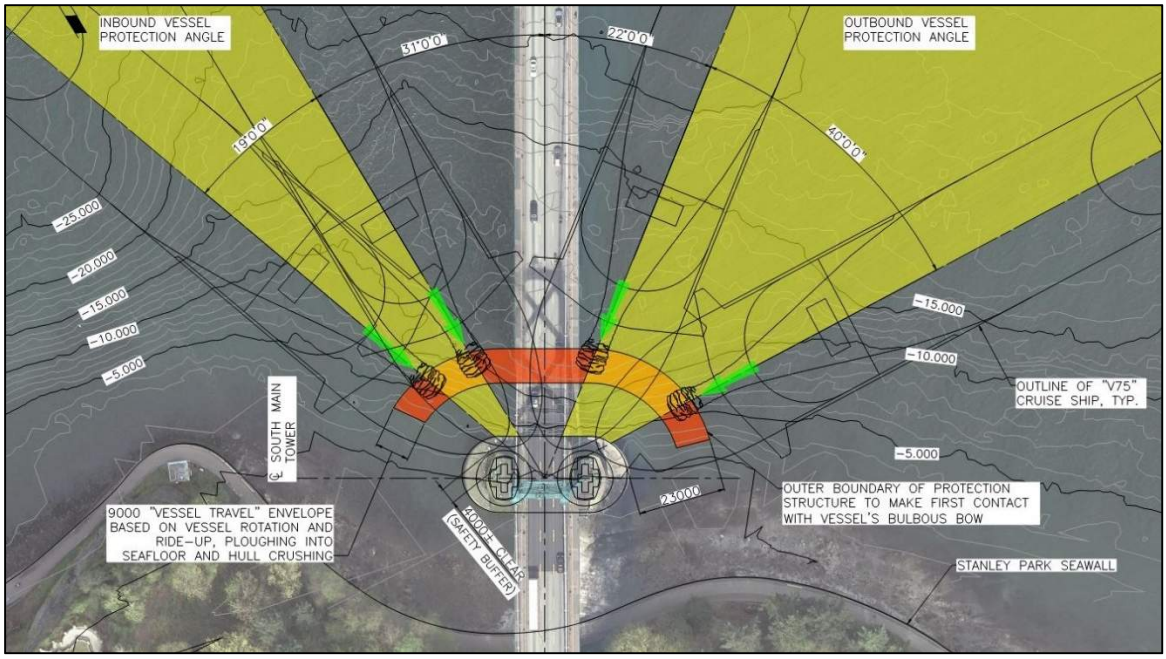



**Figure 8-4 Vessel Collision Geometric Requirements**

## 8.2.2 KEY SITE CONSTRAINTS FOR CONCEPT DEVELOPMENT

In developing protection concepts, the key site-specific considerations are as follows:

- **Hydraulics:** There is a relatively large, 5m daily tidal range. Peak currents are up to 5 knots and generally uniform across the narrows in a direction roughly parallel to the vessel transit paths. The tidal range and local currents present significant construction challenges. In addition, a new protection structure may alter the currents through First Narrows with potential impacts to vessel traffic.
- **Port and Vessel Operations:** The South Tower is located 135 m from the edge of the navigation channel. As such, there is sufficient room for a protection structure at the bridge tower without impacting the navigation channel. The area directly adjacent to the South Tower is more commonly used by small fishing / recreational vessels and log booms. Construction and permanent works will need to be cognizant of these users in terms of visibility, communication and component detailing.
- **Environmental Impacts:** The seafloor around the South Tower is valued marine habitat and suitable mitigation for any habitat loss and / or construction activities will need to be developed. The typical construction period for in-water construction is August to February to avoid adversely impacting migrant fish populations.
- **Public / Historic Context:** The Bridge is recognized as a National Historic Site of Canada and the South Tower is a prominent feature observed from close range by the popular Stanley Park Seawall. Construction and permanent works will need to be cognizant of this context in terms of visibility, communication and component detailing.

- **Geotechnical:** The exposed or shallow sandstone around the South Tower is of suitable capacity to support a structure. However, the rock is characterized as weak and can be excavated easily. Depending on the layout and type of a protective structure, settlement impacts to the existing South Tower should be confirmed at detailed design.
- **Bathymetry:** The seafloor is very shallow (i.e. exposed at low tide) behind the South Tower (towards the park) and is steeply inclined, achieving a depth of over 10m in front of the South Tower.

## 8.3 SCREENING OF PHYSICAL MITIGATION OPTIONS

Multiple physical protection options were considered for initial screening. These options were developed with appreciation for both the large geometric offset and high load/energy dissipation requirements of the vessel collision (**Section 8.2.1**), and the site-specific constraints of the South Tower (**Section 8.2.2**). These options are compared in **Table 8.1** (overleaf) and broadly categorized as follows:

1. **Standalone Pile-Supported Structure:** Vessel collision resistance is provided through a concrete and steel pile-supported structure load path to the underlying rock, independent of the bridge foundation.
2. **Dolphin Sheet Pile Cells:** Vessel collision resistance is provided through steel sheet pile cells, infilled with rock fill, and anchored to the underlying rock, independent of the bridge foundation.
3. **Rock Fill:** Vessel collision resistance is provided through a rock fill load path to the underlying rock and the existing bridge foundation. A concrete and/or steel wall-type structure could be considered to retain the rock fill and reduce the backfill footprint.
4. **Structural Load Path to the Bridge:** Vessel collision resistance is provided through a new concrete and steel structural load path to the existing bridge foundation.

Other options noted in **Section 8.1** were briefly considered but not advanced to this screening stage. For example, a traditional fendering system was not further considered because of the large geometric offset required and the size of vessels. Strengthening and/or fendering of the steel tower legs was not further considered because of the size of vessels, lack of redundancy, challenges of repair and potentially catastrophic consequences of a vessel impact. Floating protection systems were not further considered given the narrow and widely trafficked channel.

Described further in the following sections, each of the screened options are considered feasible, although some at significant cost and construction risk. Note that the evaluation is comparative and not absolute. For example, the rock fill berm is ranked “Good” with respect to capital costs, but only as compared to the other options. For some evaluation criteria (hydraulics, structural feasibility and costs), preliminary calculations were completed to help evaluate each option. For other evaluation criteria (constructability, vessel operation, environmental), the evaluation is based on qualitative expert opinion. As it relates to the two preferred options, further detail is provided in **Section 9** on each of the noted criteria.

### *8.3.1 STANDALONE STRUCTURAL OPTION*

A standalone pile-supported protection system could be installed in a variety of configurations, three shown schematically in **Table 8.1** (Options 1a, 1b and 1c). Pile groups configured strictly with vertical piles will primarily absorb energy through bending deformation whereas a battered piled system will provide higher stiffness and energy dissipation through both bending and axial deformation. The system would require a heavily reinforced concrete pilecap to distribute and engage a large group of piles in the system. Depending on the number of piles, the potential benefits of this system can be the reduced impacts to channel hydraulics and habitat. However, the number of piles required at this site significantly limit these benefits.

A key challenge of this option is the sheer number of piles required to achieve the necessary energy dissipation. This is due, in large part, to the pile lengths up to 10m +/- resulting in a very flexible structure. Even fully socketed and filled with concrete, the number of steel pipe piles will be in the hundreds to achieve the required collision energy dissipation. Pile installation would require drilling in the sandstone and, while feasible, is challenged by the First Narrows currents. The construction duration and complexity make this option high risk and very high cost and, therefore, was not advanced further to full concept development.

### 8.3.2 SHEET PILE CELL DOLPHINS

Sheet pile cell dolphins are a robust sacrificial protection system that have been used extensively at bridge sites worldwide. They could be configured in a variety of layouts at LGB to suit a preferred level of risk protection. Their primary advantage over a pile-supported structure is the increased robustness and generally lower capital costs for a large vessel collision load.

A key challenge of this option is the exposed and steeply sloping bedrock around the South Tower. Installation would require initial benching of the bedrock, challenged by the currents and significant water depth of over 10m. It would not be practical to socket the sheets in the bedrock so, instead, the cell would require extensive drilled-in anchorage with high strength steel bars. Similar to the standalone structural option, the construction duration and complexity make this option high risk and high cost and, therefore, was not advanced further to full concept development.

### 8.3.3 ROCK FILL OPTION

A **Rock Fill Berm (Option 3a)** placed in front of the South Tower provides a conceptually simply solution that is "*considered by most investigators to provide the highest level of ship collision protection*" **(5)**. Energy dissipation is achieved through a combination of passive deformation of the rock fill, rotation/ride-up of the vessel, hydrodynamic resistance as the vessel lifts and damage to the vessel's hull. While dependent on final berm geometry, the impact load path will be shared between the seafloor and the existing bridge foundation.

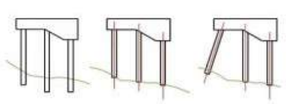
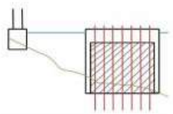
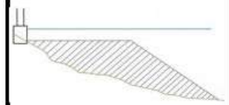
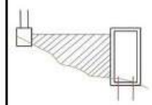
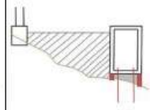
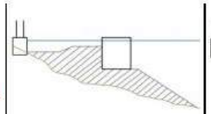
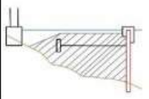
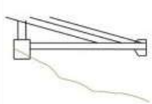
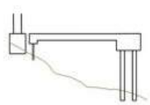
In comparative terms, the construction and maintenance of a rock fill berm is low complexity, duration and cost. As such, this option is advanced for concept development, described in **Section 9**.

A potentially adverse impact of the rock fill berm option is the large footprint and impacts to channel hydraulics and habitat. While initial review indicated these issues as not prohibitive, a variety of retaining systems were considered to reduce the size of footprint, each schematically shown in **Table 8.1**:

- **Concrete Caisson on Benched Rock (3b):** This is challenged by the rock excavation required at significant water depths. In consultation with local contractors, this option was not advanced for constructability reasons.
- **Concrete Caisson on Tremie Base (3c):** This is challenged by the logistics of setting precast segments and spud piles within narrow tide windows. In consultation with local contractors, this option was not advanced for constructability reasons.
- **Hybrid Berm / Concrete Caisson (3d):** This option was developed to address the concerns raised for Options 3a and 3b and would call for placement of a partial berm with a shorter caisson installed on top. This option is challenged by the variable depth of fill along the length of the structure and the poor compaction expected of the rock fill berm. Over time, the caissons will differentially settle in excess of 1m. In consultation with the project's geotechnical engineers and local contractors, this option was not advanced for concept development.

## 0481 Lions Gate Bridge South Tower: Vessel Collision Risk Mitigation

### *Table 8.1: Physical Protection Options Screening*

| | Criteria for Option Evaluation | 1. Standalone Pile-Supported Structure: 1a-Socketted Piles | 1. Standalone Pile-Supported Structure: 1b-Anchored Piles | 1. Standalone Pile-Supported Structure: 1c-Battered Piles | 2. Dolphin Sheet Pile Cells | 3. Rock Fill: 3a-Rock Fill Berm | 3. Rock Fill: 3b-Caisson on Benched Rock | 3. Rock Fill: 3c-Caisson on Tremie Base | 3. Rock Fill: 3d-Hybrid Berm / Caisson | 3. Rock Fill: 3e-Combi-Wall (Pipe & Sheet Piles) | 4. Structural Load Path to Bridge: 3a-Cable-Supported | 4. Structural Load Path to Bridge: 3b-Pile-Supported |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | |  | | |  |  |  |  |  |  |  |  |
| Load Path | Energy Dissipation<br>*Is it rigid or can it absorb energy?* | ✓ | | | ✓ | ✓ | ~ | ~ | ~ | ~ | ✗ | ~ |
| | Resilience and Scaleabilty<br>*Can it be fine-tuned for different risk levels?* | ~ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ |
| | Low Reliance on Energy Dissipation through Existing Bridge Components | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ~ |
| Impacts and/or Risks | 1st Narrows Hydraulics | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Commerical Port Operation | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Smaller / Recreational Vessels | ~ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | ~ |
| | Environmental Impacts | ✓ | | | ~ | ~ | ~ | ~ | ~ | ~ | ✓ | ✓ |
| | Public / Historic | ~ | | | ~ | ✓ | ~ | ~ | ~ | ~ | ✗ | ✗ |
| | Construction Duration | ✗ | | | ✗ | ✓ | ✗ | ✗ | ✗ | ~ | ✗ | ✗ |
| | Construction Complexity | ~ | | | ✗ | ✓ | ✗ | ✗ | ✗ | ~ | ✗ | ~ |
| Costs | Capital | ✗ | | | ✗ | ✓ | ✗ | ✗ | ✗ | ~ | ✗ | ✗ |
| | Maintenance | ~ | | | ~ | ✓ | ~ | ~ | ~ | ~ | ✗ | ~ |
| | ***Advance to Concept?*** | **No** | | | **No** | **Yes** | **No** | **No** | **No** | **Yes** | **No** | **No** |

**Legend:** ✓ *Good / Low Impact* ~ *Moderate / Some Impact* ✗ *Poor / High Impact / Potential "Show-Stopper"*

- **"Combi-Wall" (Pipe and Sheet Piles) (3e):** This option was recommended by local contractors as a constructible solution, used extensively in marine applications. It calls for socketed steel pipe piles spaced at regular intervals with steel sheet piles serving as infill elements between the pipe piles. The system is stabilized through anchorage into the rock fill. This option is expected to be considerably more expensive than a rock fill berm but advanced for concept development, for comparative purposes.

### 8.3.4 STRUCTURAL LOAD PATH TO THE EXISTING BRIDGE OPTION

The existing concrete protection collar at the base of the South Tower has high strength intended to resist vessel collision loading. As such, a third category of physical protection was considered that would establish a load path between the outer boundary of first contact (**Figure 8-4**) and the existing bridge foundation. Note that the existing bridge foundation is a critical vertical load path element to the bridge and must remain effectively undamaged after a vessel collision. As such, the existing collar is designed for high strength and rigidity. In this case, energy dissipation from a vessel collision occurs primarily through damage to the vessel, rather than the structure. From a marine perspective, this strategy is less favourable as there are higher risks to port operation and the environment. In addition, the combination of vertical and lateral load paths has limited redundancy and presents a higher potential consequence to overload or unexpected load combination scenarios.

Two options were considered for this third category: (4a) Cable-Supported; and (b) Pile-Supported. Both options are shown schematically and tabulated in **Table 8.1**. The Cable-Supported option (4a) presents considerable complexity and cost, and is generally not compatible with the level of robustness typically required for marine protection structures.

The Pile-Supported option (4b) would be comprised of a heavy concrete slab to serve as an in-plan diaphragm to transfer vessel impact loads from a variety of potential collision angles. The slab would be supported on steel pipe piles which, in addition to vertical support, could provide partial energy dissipation to the system. This option is challenged by the size and volume of structural components (precast/cast-in-place concrete, steel) and their high cost for supply and installation.

As a direct structural load path, both options would rely on the full strength capacity of the existing tower pedestal and foundation. If they were advanced to detailed design, the foundation capacity would require confirmation and possible enhancement for reliability. Also, both options are challenged by a potential safety hazard relating to recreational vessels caught under the slab during a rising tide. And finally, a massive slab projecting from the base of the bridge would be viewed unfavourably due to impacts to the aesthetics and historic character of the bridge. While none of these issues are unsurmountable, they contribute to the larger challenges of very high cost and complexity. As such, both of the options under Category 4 were not advanced for concept development.

# 9 PHYSICAL MITIGATION CONCEPTS

## 9.1 CONCEPT TYPES AND CONFIGURATION

Based on the option screening review summarized in **Section 8.3**, two preferred rock fill options were identified for concept development. The Protection Berm (3a) and the Combi-Wall (3e) concepts are presented in **Drawings 01481-C002** and **01481-C003** (respectively) in **Appendix C**. Both options provide vessel collision resistance primarily through a rock fill load path to the underlying rock. While the berm option is comprised solely of rock fill material, the combi-wall introduces structural retaining components to reduce the volume of fill by about 35% and the sea floor footprint by about 50%.

Note that the final configuration (strength, stiffness and geometry) of the selected concept will be determined based on the degree of vessel collision protection desired by the Ministry. The configuration for the two proposed concepts are intended to provide protection for all vessel types currently transiting First Narrows. These concepts are expected to be confirmed and optimized at a future detailed design stage. Each concept is described in further detail in the following sections. Additional considerations and impacts relating to hydraulics, port operation, environment, the public and aesthetic considerations are generally similar for both concepts and summarized in subsequent sections.

### *9.1.1 ROCK FILL PROTECTION BERM OPTION*

The rock fill berm option is conceptually simple in that an aberrant vessel runs aground on the front slope of the rock fill berm before reaching the South Tower. Energy dissipation is achieved through a combination of passive deformation of the rock fill, rotation/ride-up of the vessel, hydrodynamic resistance as the vessel lifts and damage to the vessel's hull.

**Top of Berm Elevation:** The proposed berm concept has a top bench elevation of 3.2m (mean water level plus sea level rise), considerably higher than the minimum EL. -4.0m suggested by the risk evaluation to achieve the 1 in 10,000 year AFC return period. Note that this proposed elevation matches closely to the water elevation shown in the photograph included in **Drawing 01481-C002.** This top of berm elevation, to be refined at detailed design, was established for this study based on the following considerations:

- Several metres of rock fill overburden are required to ballast the berm to provide the required passive resistance capacity.
- At mean water level, the rock fill introduces new high-value inter-tidal habitat, partially offsetting the permanent impacts to the seafloor.
- Reliable vessel collision protection is provided for all transiting vessels, for a relatively small incremental cost.

**Berm Location:** The outer crest of the proposed berm is located 20m from the face of the South Tower protection collar. By using a 1.5(H):1(V) front slope of the berm, this offset ensures that first grounding occurs beyond the 23m "outer protection boundary" at all water levels, as prescribed in **Section 8.2.1**.

**Back-Slope Geometry:** The proposed berm concept includes a back-slope towards the existing South Tower foundation. This detail was included to (a) reduce the amount of rock fill material; and (b) increase the area of lower intertidal habitat. However, this zone could be considered for infill if an enhanced load path to the bridge foundation was deemed necessary at detailed design.

**Vessel Collision Scenarios:** A series of collision scenarios were reviewed based on the governing vessels transiting First Narrows, each shown in **Drawings 01481-C004** through **01481-C010** in **Appendix C**. For each

scenario, a length of vessel travel is included to account for the noted energy dissipation mechanisms that occur during vessel grounding. Note that the vessel grounding analysis for this South Tower berm concept are based on the risk assessment analyses completed for the similarly configured rock berm at the North Tower. This analysis is described in detail in **Section 5**. Further vessel grounding analysis will be required at the detailed design stage.

**Governing Vessel Scenario:** From review of each of the collision scenarios, the governing vessel in terms of bow flare is the largest of the cruise vessel categories (121,900 GT cruise ship) considered in the risk assessment study. Based on an estimated vessel travel of 9m after first grounding, the tip of the flared bow approaches within about 6m of the steel legs. Other scenarios indicate a larger safety buffer, although in ballasted condition, some vessels (typically tankers and bulkers) have relatively shallow drafts and the passive berm capacity assumed by the grounding analysis may not be wholly achievable. Detailed analysis may determine that a taller berm or infill of the berm's back slope is required to ensure passive capacity and maintain an appropriate safety buffer.

**Rock Fill:** The outer zone of the rock fill berm will require a heavy riprap protection to ensure stability when exposed to the First Narrows currents and wave-action. The North Tower rock fill berm (**Figure 3-1**) serves as a relevant reference-point for preliminary selection of this material given its 30-year demonstrated stability at First Narrows. As such, for concept development and cost estimating purposes, a 1200 mm minus quarry rock riprap is assumed for the outer zone of the berm. The interior (majority) portion of the berm can be smaller (300-450 minus) reclaimed quarry rock.

**Construction Considerations:** The rock fill material would be transported to site by barge and either (a) placed directly at the berm site; or (b) first stockpiled in the shoreline zone behind the tower, before final placement with equipment from shore. For direct placement in deeper water zones (over 6m), the rock fill material can be efficiently placed with a "dump barge". For direct placement in shallower water, the rock fill would be placed with a clam shell bucket. To maintain placement control and minimize waste, a perimeter of riprap would first be established to contain the quarry rock.

The option of first stock-piling material on the foreshore introduces additional cost for double-handling, additional waste and larger temporary environmental impacts. However, a benefit of this approach is that the final placement operation from shoreline is far less sensitive to the tide cycle.

The construction duration for this option will be determined by the available work windows for equipment in the prevailing currents, VFPA and PPA requirements to be clear of the channel for vessel navigation, and weather. With careful pre-planning, it is reasonable to assume the work could be completed in one six-month environmental window, with a further six-month allowance for work before and after the placement window for planning, survey and completion activities.

**Long-Term Maintenance Considerations:** With no structural components, there is little long-term maintenance to the rock fill berm. Some long-term subsidence can be expected and periodic topographic survey is expected. In the event of more severe storms, it may be necessary to re-profile and/ supplement the armour rock facing.

**Future Repairability / Scalability / Dismantling:** In the event of a vessel collision with a large vessel, the rock fill berm would experience minor local damage that could be relatively easily repaired by the placement of additional rock. Modifying the berm geometry for future vessel traffic and ultimate dismantling would be a time-consuming but relatively straight-forward exercise.

### *9.1.2 COMBI-WALL OPTION*

The combi-wall is a retaining structure comprised of closely-spaced steel "king piles" with lighter steel sheet piles serving as infill. The king piles are typically constructed of heavy pipe or I sections that serve as the primary lateral load resisting component, restrained at both the base and top of the piles. The proposed

concept for the South Tower, shown in **Drawing 01481-C003** (**Appendix C**) and schematically in **Figure 9-1**, is configured with the top of the main wall tied back to a sheet pile anchor wall. For vessel collisions, the main wall serves as a vertical barrier that pushes in and engages the passive capacity of the retained rock fill. Collision energy dissipation comes from components similar to the berm option; however the crushing of the vessel hull is a significantly higher proportion.

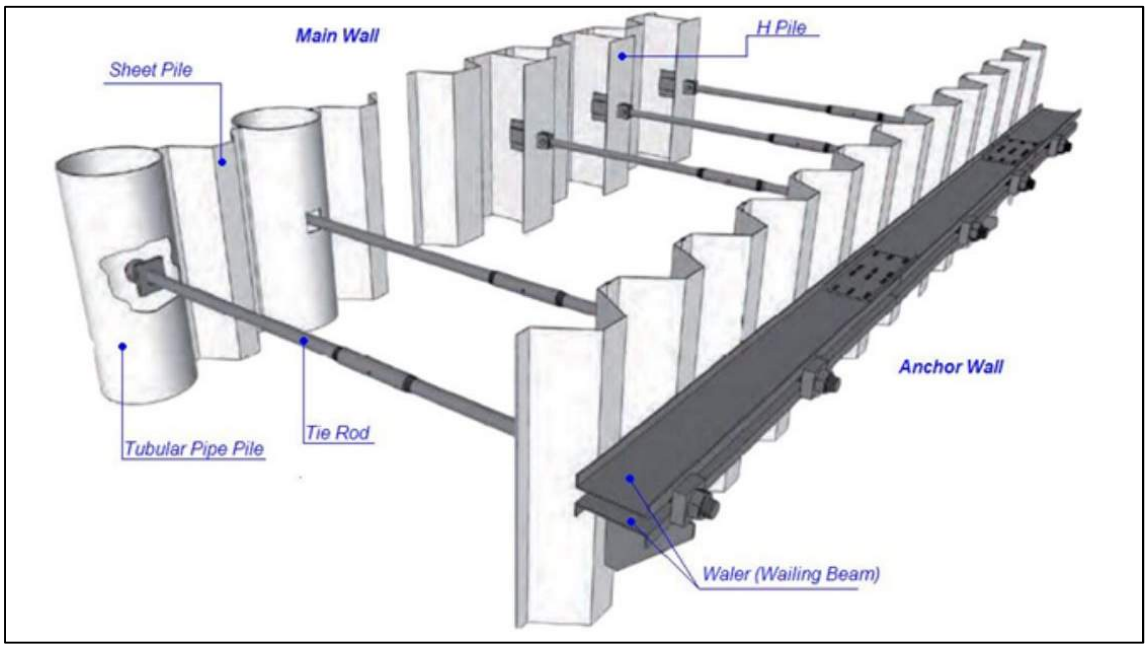



**Figure 9-1: Combi-Wall Components Sketch**

**Top of Wall / Fill Elevation**: The top of retained fill is set at EL. 4.30 (MHW plus sea level rise) and the top of the main wall is nominally higher, set to EL. 4.50 (matching HHWMT plus sea level rise). Note that these elevations are 1.1m higher than the top of bench elevation specified for the rock fill berm option (**Section 9.1.1**). The increase is primarily to facilitate the installation of the tie rods and concrete coping beam at manageable water levels.

**Wall Location:** The outer face of the wall is located 23m from the face of the South Tower protection collar, matching the outer boundary vessel collision geometry prescribed in **Section 8.2.1**. While established for vessel collision requirements, this offset provides adequate space to locate the sheet pile anchor wall behind the active soil wedge for the main wall, and ensure the stability of the wall for retained fill loading.

**Vessel Travel Distance after First Bow Contact:** The vertical face of the combi-wall presents little opportunity for collision energy dissipation through vessel rotation and ride-up, as compared to the berm option. Instead, a significantly larger proportion of energy dissipation will occur through crushing of the vessel hull. The mechanics of vessel hull crushing are beyond the scope of this study and, therefore, a simplified allowance of 9m of vessel travel was specified. This value was set to match the ploughing / ride-up length used for the rock fill berm analysis. This value is viewed as conservative since the high strength and stiffness of a steel hull assures a shorter travel distance to achieve a comparable magnitude of energy dissipation.

**Governing Vessel Scenario:** Given the geometric similarities between the berm and combi-wall options, only the governing vessel scenario, the 121,900 GT cruise ship, is included in **Drawing 01481-C011** in **Appendix C**. Using a 9m vessel travel from first contact of the bulbous bow, the tip of the flared bow approaches within about 4m of the steel legs.

**Wall Components:** Initial concept development indicates a 914mm diameter pipe pile with 25mm wall thickness is feasible. A relatively heavy wall thickness is expected to (a) reduce the amount of temporary tie-back during construction; and (b) provide sacrificial thickness for long-term performance. A concrete infill of the piles is proposed to further reduce corrosion exposure. Note that a larger pile diameter could offer material efficiencies but presents installation challenges at the site. The pipe piles would likely require socketing four to six pile diameters into sound rock. Backfill will be a combination of quarry fines and rock. A coping beam is proposed along the top of the combi-wall to provide collision load distribution, visual delineation for recreational boaters and an aesthetically pleasing finish to the top of the wall which will be exposed at most times of the tide cycle.

**Construction Considerations:** A key challenge of the combi-wall is the drilling and installation of the king piles within high currents and short slack-tide windows. Drilling requires a stable platform and will be very difficult from floating equipment. An alternative approach could be to drill from a falsework platform or a shore-accessed fill berm. Note that, compared to the berm option, any of these options introduces significantly greater disruption to the park users and environment.

The rockfill operation will be similar to that described for the berm. Until the sheetpile anchor wall is fully engaged, the existing South Tower foundation could serve as a temporary anchorage for the combi-wall during the backfilling operation.

The construction duration for this option is variable, depending on permit restrictions. Given the challenges of pile installation, the in-water works will likely be up to 12 months, and would be required to span across two environmental windows. As such, the total duration of construction for the combi-wall is expected to be two years, and potentially longer depending upon stakeholder considerations and authorizations.

**Long-Term Maintenance Considerations:** Unlike the berm concept, the combi-wall has steel and reinforced concrete components that will deteriorate over the structure's service life. Furthermore, the exposed steel faces of the wall will be exposed to high currents and fine sediment movement that will accelerate the deterioration of a conventional coating. One solution could be a cathodic protection system, although local bridge and marine experience (including both impressed current and sacrificial anodes) has not been favourable for this strategy. A practical and likely solution to achieve a 50+ year service life is (a) a high-performance coating to exterior faces (outside of pipes, both sides of sheet piles); and (b) an allowance for structural section loss due to corrosion. The tie rods are located within the inter-tidal zone and a double-corrosion protection (DCP) system comprised of plastic sheathing and concrete grout is required for corrosion protection. Similarly, the concrete coping beam is within the inter-tidal zone and would be reinforced with stainless steel reinforcement.

**Future Repairability / Scalability / Dismantling:** In the case of a collision event, the options for repair have the same complexity as the original construction. Portions of the sacrificial combi-wall would experience significant local damage and would need to be replaced after a major accident. Similarly, future upgrade or dismantling of the combi-wall will be significantly more complicated than the berm option.

## 9.2 HYDRAULIC IMPLICATIONS

The hydraulic implications of the rock fill berm were analyzed by specialist sub-consultants Northwest Hydraulics Consultants (NHC). Details of this analysis are included in the NHC memo included in **Appendix D**. The following provides a summary of NHC's analysis and findings.

Of the two options, only the rock fill berm option was analysed. Because the combi-wall option has a smaller footprint, the hydraulic impacts of the berm option are expected to govern. Also note that the hydraulic analysis was based on an interim concept of the study that was subsequently updated to the concept shown in **Drawing 01481-C0002**. The modelled concept is slightly taller (EL. 4.00 vs EL. 3.20) but narrower (16m vs 20m)

than the final concept. The implications of this change are expected to be inconsequential but will require confirmation at the detailed design stage.

### 9.2.1 HYDRODYNAMIC MODEL SUMMARY

A hydrodynamic model of Burrard Inlet was developed (**Figure 9-2**) that includes English Bay, Vancouver Harbour and Indian Arm. The model was developed using Delft3D, a 3D hydrodynamic model, which calculates non-steady flow and transport phenomena that result from tidal and river flow forcing on a rectilinear or a curvilinear grid. The Burrard Inlet model consists of three, 2-way coupled domains with a progressively finer resolution. The finest grid resolution is near the First Narrows with a grid size of 5m. In the vertical direction, the model consists of 15 layers. Tides are simulated with amplitudes and phases of 16 locally-dominant tidal constituents along the open ocean boundary (Point Atkinson). The bathymetry is based on hydrographic charts and VFPA survey data. The model was validated against water levels at Vancouver Harbour and the 1981 Vancouver Harbour Tidal Current Atlas.

For the assessment, the November 14-15, 2012 tidal cycle was selected. This cycle was selected since it has a large tidal range of 4.1m. Note that strong currents are associated with large tidal swings and will have greater influence on vessel navigation, a key consideration in the review of mitigation concepts.

**Figure 9-2: Hydrodynamic Model Extents**

### 9.2.2 ANALYSIS FINDINGS

The hydrodynamic model was run with and without the rock fill protection berm and the current velocities were compared. The velocity difference for peak ebb and flood tides are shown in **Figure 9-3** and **Figure 9-4**, respectively. Note that these figures show surface flows. Velocity differences at EL. -5.00 and EL. -10.00 (CD) are included in **Appendix D** and indicate that the greatest impact is at the surface and decreases with depth.

A key finding of this analysis is that the increase in velocity in the navigation channel is less than 0.1 m/s. Under ebb tide, a slight velocity increase (< 0.2 m/s) is observed along the north side of the channel, west of the bridge. Other observations include the following:

- The berm itself presents a drag on local currents with velocity reductions of up to 1 m/s downstream of the South Tower (well outside the navigation channel).

- Back eddy circulation is observed along the shoreline, with increases of 0.3 m/s under flood tide. During ebb tide, some local increases occur between the tower and the shoreline of up to 0.7 m/s. Again, these impacts are still minor and well outside the navigation channel.

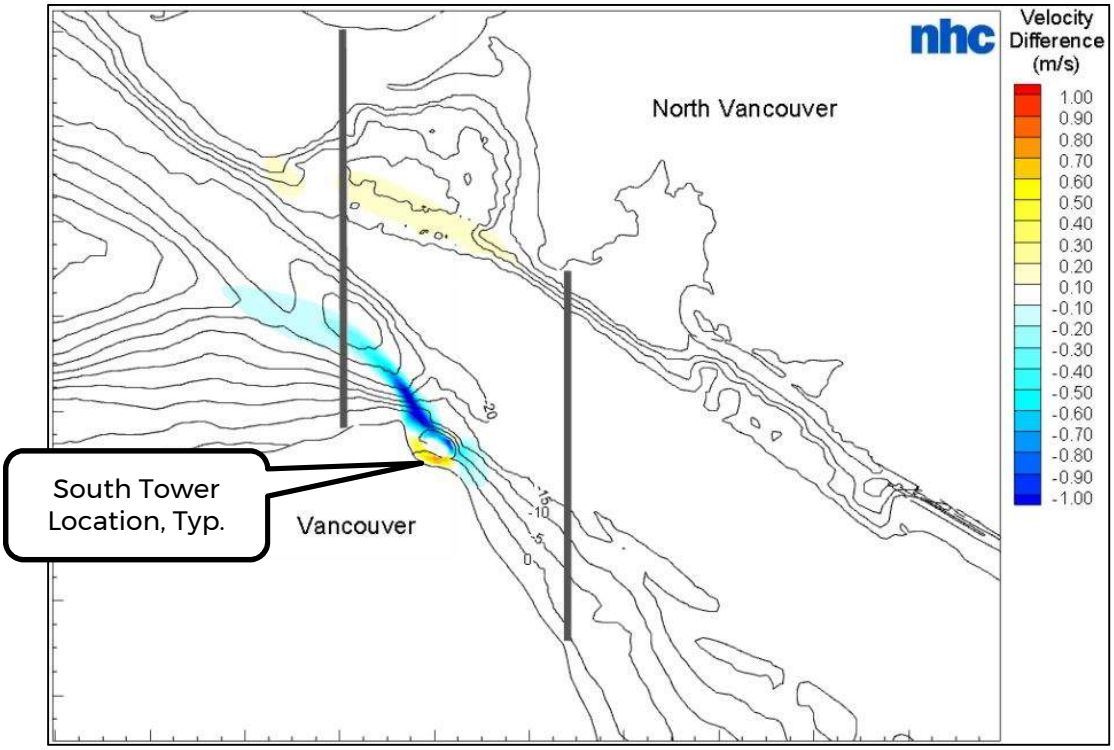



**Figure 9-3: Change in Current Velocity due to Proposed Berm at South Tower – Peak Ebb Tide**

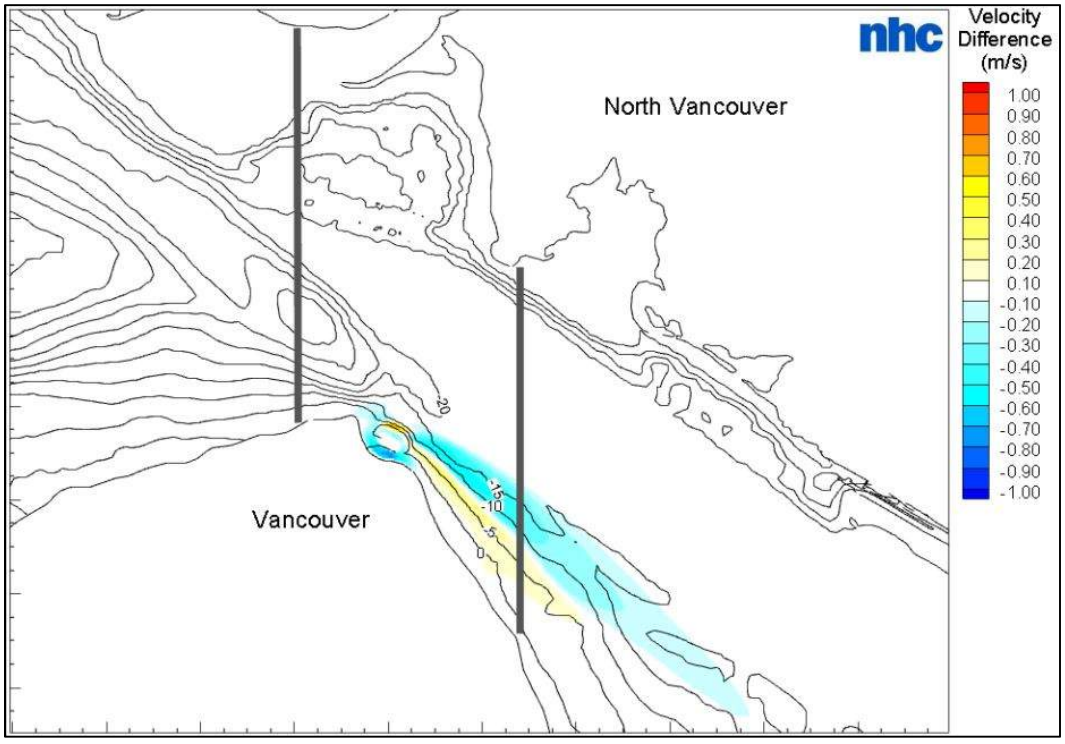



**Figure 9-4: Change in Current Velocity due to Proposed Berm at South Tower – Peak Flood Tide**

## 9.3 IMPACTS TO PORT AND VESSEL OPERATIONS

The new rock fill berm and combi-wall structure in the two proposed concepts are located well outside (>100m) the navigation channel. In consultation with the VFPA, these new features do not present a concern for physical conflict with commercial vessel traffic.

The VFPA's primary concern is that the structures would modify the currents through First Narrows negatively impacting vessel navigation. As summarized in the previous section and further detailed in the Northwest Hydraulics Consultants (NHC) memo, included in **Appendix D**, the hydraulic impacts of the rock fill berm were estimated. From this analysis, the overall findings were that (a) peak flow velocities were increased by less than 0.1 m/s, relatively uniformly across the channel with no notable new cross-currents introduced; and (b) some slightly higher impacts, primarily reductions, observed in close proximity to the berm, well outside the navigation channel. The VFPA has confirmed that these small alterations to the currents do not materially affect vessel navigation and are acceptable.

The area directly adjacent to the South tower is more commonly used by tug boats, log booms and recreational vessels. Both protection concepts reduce but do not prohibitively exclude the use of the side-of-channel for such smaller vessels. Navigation beacons are expected to be required to visually delineate the new protection structure. A benefit of both concepts is that, unlike a pile-supported structure, there is no risk of a small recreation vessel (small motorboat, sea kayak) becoming entangled in the piles or entrapped under a slab in a rising tide.

## 9.4 ENVIRONMENTAL CONSIDERATIONS

The proposed rock fill placement at the South Tower has several environmental permitting considerations related primarily to impacts to fish and fish habitat and water quality, and fish habitat loss. Several permits are anticipated for this work:

- A **Fisheries Act Authorization** from the Department of Fisheries and Oceans Canada (DFO). The *Fisheries Act Authorization* process includes two steps with DFO: **(1)** the Request for Project Review and the **(2)** Application for Authorization, if DFO determines that an authorization is required, typically when serious harm to fish cannot be avoided or mitigated. The Application for Authorization includes the content of the Environmental Assessment (completed as part of the Request for Project Review) plus a Compensation Plan and a letter of credit to cover the costs of the compensation plan.
- A **Project and Environmental Review Permit** from the VFPA. The project is expected to meet the VFPA's criteria of a Category B project and will require technical analysis and mitigation relating to fish and fish habitat, marine water quality and a construction environmental management plan. In addition to the application and technical reports, public notification and stakeholder / indigenous peoples consultation may be required. Prior to submitting the application, the Ministry will have to secure tenure with the port's Real Estate department in what would be a similar arrangement to the tenure agreement for the bridges.
- An **Aquatic Crown Land Lease** may be required from the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) if the works extend outside of the VFPA's jurisdiction. The tenure would be for a period of 30 years. In this case, Aquatic Crown land means that land below the visible high water mark of a body of water, extending offshore to the recognized limit of provincial jurisdiction, including the foreshore. The application would include a legal survey, preparation of Site

Plan and Management Plan, notification of adjacent owners and indigenous peoples consultation. Archaeological investigation may be required; however, unlikely given there is not a major excavation.

## 9.5 PUBLIC AND HISTORIC CONTEXT

The two proposed concepts will be visible at relatively close range from the Stanley Park seawall. Both will be seen as a rocky breakwater that wraps around the sides and in front (north of) the South Tower. The top of the rock fill for the Protection Berm Option is set to MWL (plus sea level rise) and, as such, will daylight above the water surface for about half of the tide cycle. The top of the rock fill for the combi-wall option is set to MHW, 1.10m above MWL and therefore, will be more exposed for longer periods of the day.

For construction, material supply will be by barge. If available, the Stanley Park Seawall could serve as a useful on-shore link for small vehicles and equipment. For construction of the protection collar in 1988, the seawall was not used but blocked off for certain construction operations. The foreshore area between the South Tower and the seawall was temporarily infilled to serve as a lay-down area. The combi-wall option presents significantly more disruption to the users of the seawall including noise from drilling, pile installation and equipment operation in the foreshore area.

## 9.6 ESTIMATED COSTS

An order-of-magnitude cost estimate was prepared for each of the physical mitigation options and is summarized in **Table 9.1**. Further detail relating to these cost estimates are included in **Appendix E**. The cost estimate includes material quantity take-offs and unit rates for key components. Construction unit rates were established in consultation with local contractors. In addition, these cost estimates consider pre-construction activities including geotechnical investigation, detailed analysis and design and permitting. The cost estimates also include the expected costs during construction including environmental compensation, management / engineering review and contract administration services. A 50% contingency rate was used in the cost estimate to reflect the uncertainty associated with concept-level design development.

**Table 9.1: Cost Estimate Summary**

| OPTION | COST ESTIMATE WITH CONTINGENCY |
|---|---|
| Rock Fill Protection Berm | $15M |
| Combi-Wall Protection | $25M |

# 10 SUMMARY OF KEY FINDINGS

This report provides a summary of the detailed vessel collision risk analysis of the LGB. The analysis estimated the AFC due to vessel collision for the Base Case (Present Day Vessel Traffic) has a return period of 5,236 years. The estimated AFC for the Base Case (Future Vessel Traffic; 25 Year Horizon) has a return period of 4,091 years. These results indicate that the AFC meets the criteria for a Class II (Regular Importance) highway bridge but does not meet the criteria for a Class I (Critical Importance) highway bridge. Key findings of the risk analysis are summarized as follows:

1. The primary bridge vulnerability is the potential impact of the flared bow of a container, general cargo or cruise ships with the South Tower steel legs at elevations significantly above the water. The overhang of the flared bow could contact the tower leg at a relatively weak structural location high above the water before the portion of the ship's bulbous bow below the water contacts the concrete pedestal / foundation.
2. The potential vulnerability of the concrete pedestal / foundation is low since the resistance strength of these bridge components is very high. Therefore, the risk of collapse resulting from tankers and bulk carrier impacts (which have blunt bows and contact the South Tower concrete protection collar on the foundation at or below the waterline) is not significant.
3. Over 80% of the collision risks to the bridge are due to outbound vessels. This is because of the South Tower's location inside the inbound turn in the channel and its partial protection inside a small cove with shallow water depths.
4. The North Tower is protected from vessel collision by an existing rock berm island protection system. An analysis of potential vessel grounding and ride-up on the rock berm performed as part of this study confirmed that vessels would be safely stopped before potential contact was made by the flare of ship bows above the water with the tower leg or by the bulbous bow of the ship with the concrete pedestal of the tower.
5. Reducing the water depth near the South Tower from the existing El -7.0m to a revised elevation of El -4.0m (or less) would result in return periods exceeding 10,000 years. This change in risk is related to the larger container, general cargo, and cruise ships, which start to run aground at these depths. A reduction in water depth could be accomplished by an underwater berm or by a protection island similar to the North Tower.

This report provides concept-level details and discussion of physical protection measures to address a potential vulnerability of the LGB South Tower legs to impact from a vessel's flared bow. Design development first considered key site constraints in developing a wide-range of feasible physical protection options. From this initial review, two options, **3a-Protection Berm** and **3e-Combi-Wall** were identified as suitable for concept design development. While the berm option is comprised solely of rock fill material, the combi-wall introduces structural retaining components to reduce the volume of rock fill by about 35% and the sea floor footprint by about 50%. Note that neither option relies on the strengthened foundation of the South Tower as a primary load path. By de-coupling the collision load path from the critical vertical load path of the South Tower, there is greater system reliability and less risk of public disruption or bridge closure for repairs after a potential vessel collision event.

**Table** 10.1 provides a comparison of the two concepts based on various criteria discussed throughout the report. The evaluation is simply comparative between the two options. A green checkmark (✓) indicates a good rating or low impact. A brown tilde (~) indicates greater impacts or lesser performance compared to the other option.

The rock fill berm option is the preferred concept based on several key project criteria and has an estimated capital cost of **$15M**. While the combi-wall does present notable savings in terms of rock fill quantity and seafloor footprint, these savings do not translate to a significant overall benefit to the project.

**Table 10.1: Comparison of the Two Concepts Based on Various Criteria**

| CRITERIA | BERM | COMBI-WALL | COMMENT |
|---|---|---|---|
| **Vessel Collision Protection** | ✓ | ✓ | As configured, both options significantly reduce vessel collision risks at the South Tower and meet the Code requirements of a 10,000 AFC return period for a Class I (Critical Importance) highway bridge |
| **Energy Dissipation** | ✓ | ~ | The rock fill berm provides excellent energy dissipation through vessel ploughing and ride-up. The combi-wall introduces a much higher degree of damage to the vessel's hull with greater potential implications to port operation and the environment |
| **Low Reliance on Energy Dissipation through Existing Bridge** | ✓ | ✓ | Both options provide vessel collision resistance primarily through a rock fill load path to the underlying rock. Depending on final rock fill geometry, some loading may be transferred to the existing bridge foundation. Because of attenuation through the rock fill, this loading is well within the expected capacity of the existing foundation. |
| **Hydraulic Impacts** | ✓ | ✓ | The two options have a similar magnitude of impact to the First Narrows currents. The increase in currents in the navigation channel is a small net increase of 0.1 m/s +/- and uniformly distributed. |
| **Commercial and Recreational Vessel Operation** | ✓ | ✓ | Both options are located well outside the navigation channel and do not present a physical hazard to vessels in First Narrows. The VFPA has indicated that the change in currents do not present a significant concern for commercial vessel traffic. The VFPA will require further analysis and consultation with marine users as the design is developed. |
| **Environmental Impacts** | ~ | ~ | The two options have a similar overall magnitude of impact to habitat. With a somewhat larger footprint, the berm concept may require higher compensation measures. |
| **Public / Historic Impacts** | ✓ | ~ | From the well-trafficked seawall, both options will appear as a rocky off-shore breakwater, visible only during lower tide periods. The combi-wall would be slightly more prominent due to a higher top of fill. Also, construction for the combi-wall will be more disruptive to seawall users. |
| **Design and Construction Duration** | 1 year | 3 years | Berm construction can likely be completed in one six-month environmental window (1-year total duration). Combi-Wall construction is expected to require 2 environmental windows (3 years total duration) |
| **Construction Complexity** | ✓ | ~ | Combi-wall presents considerably higher complexity and risks. |
| **Capital Cost** | **$15M** | **$25M** | The combi-wall is significantly higher cost than the berm concept. |
| **Maintenance Cost** | ✓ | ~ | The berm concept requires minimal maintenance. The combi-wall concept will require periodic maintenance although this cost can be mitigated by including a structural allowance for exposed components and simply allowing them to deteriorate over their service life. |
| **Future Reparability Scalability / Dismantling** | ✓ | ~ | The berm concept is relatively simple to repair, modify or dismantle at end of service life, when compared to the combi-wall concept. The combi-wall is a sacrificial structure and would require significant repairs or replacement after a major vessel impact. |

# 11 ACKNOWLEDGEMENTS

The project has served as an intensive collaboration between the Ministry and the consultant team, with key members of the Project Team all noted at the beginning of the report. In addition, special acknowledgement is extended to Kevin Baskin, the Ministry's former Chief Bridge Engineer who led the early stages of the project.

The project has required extensive and on-going co-operation with the VFPA. Grateful acknowledgement is extended to Sean Baxter, Egge Kloosterboer, Dave Hart and Jeffrey Pelton for their assistance and valued feedback.

In addition, the following people and organizations are acknowledged for their valuable insights relating to vessel operation in Burrard Inlet and BC coastal waters: (a) Paulo Ekkebus and Brian Young of the Pacific Pilotage Authority; (b) Paul Devries and Captain Robin Stewart of the BC Coast Pilots; and (c) Mohan Raman of the Transportation Safety Board of Canada.

Appreciation is extended to COWI (formerly Buckland & Taylor) for assisting in locating past files and reports related to the IWMB. Appreciation is also extended to Gord Helm of the Halifax Harbour Bridges for providing background and insight relating to similar issues for the Macdonald and MacKay Bridges in Halifax.

# 12 REFERENCES


1. **Buckland and Taylor.** Lions Gate Bridge Study, Report #13, Ship Collision Protection - North Tower. Vancouver : British Columbia Ministry of Transportation and Infrastructure, 1984.
2. **Buckland and Taylor .** Lions Gate Bridge Study, Report #14, Ship Collision Protection - South Tower. Vancouver : British Columbia Ministry of Transportation and Infrastructure, 1986.
3. **Buckland and Taylor .** Lions Gate Bridge, Ship Collision Assessment for the North and South Towers. Vancouver : British Columbia Ministry of Transportation and Infrastructur, 1997.
4. **Canada Standards Association.** Canadian Highway Bridge Design Code (CAN/CSA-S6-14) . Toronto : s.n., 2014.
5. **American Association of State Highway and Transportation Officials (AASHTO).** Guide Specification and Commentary for Vessel Collision Design of Highway Bridges, 2nd Edition, with 2010 Interim Revisions. Washington, DC : s.n., 2009.
6. **American Association of State Highway and Transportation Officials (AASHTO).** LFRD Bridge Design Specifications, 7th Edition. Washington, DC : s.n., 2014.
7. **Canadian Standards Association.** Canadian Highway Bridge Design Code (CAN/CSA-S6-14). Toronto : s.n., 2014.
8. **Canadian Coast Guard.** Vulnerability of Bridges in Canadian Waters. s.l. : Transport Canada, 1982.
9. **National Geospatial Intelligence Agency.** Sailing Directions, British Columbia. 2014.
10. **Vancouver Fraser Port Authority.** Port Information Guide. s.l. : Vancouver Fraser Port Authority, October 2017, Amended February 2018.
11. **Geological Suvey of Canada.** Tabulated Values of Relative Sea-Level Projections in Canada and the Adjacent Mainland United States. 2015.
12. **Hodge, W.E.** Geotechnical Aspects of Lions Gate Bridge South Pier Ship Protections Works. Vancouver : s.n., May 1987.
13. **Canadian Register of Historic Places.** Canada's Historic Places. [Online] 03 13, 2009. http://www.historicplaces.ca/en/rep-reg/place-lieu.aspx?id=11711.
14. **City of Vancouver Parks & Recreation.** Vancouver Waterfront Inventory. 2011.
15. **Trans Mountain Expansion Project.** Termpol Review Process Documents, 15 Volumes (Termpol 3.1 thru Thermpol 3.19) plus Supporting Documents and Reference Materials. November 29, 2013.
16. **Fletcher, May and Perkins.** "Pier Protection by Man-Made Islands for Orwell Bridge, UK. Copenhagen. : IABSE Colloquium on Ship Collisions with Bridges Offshort Structures, 1983.
17. **Seah, C. and Baker A.** Maritime Accidents and Human Perfomance the Statistical Trail. s.l. : American Bureau of Shipping, 2004.
18. **Larsen, O. (Editor).** Ship Collision with Bridges: The Interaction between Vessel Traffic and Bridge Structures. s.l. : International Association for Bridge and Structural Engineering (IABSE), 1993.

# APPENDIX

# A

## BASE CASE (FUTURE VESSEL TRAFFIC; 25 YEAR HORIZON) VESSEL COLLSION RISK ANALYSIS

# APPENDIX

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**** Note ** All references to "Base Case 2" in Appendix A are equivalent to "Base Case (Future Vessel Traffic) as described in the report.**


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- Vessel Fleet Annual Trip Frequency - Distribution (Page A1.2)

*APPENDIX A2 - ANNUAL FREQUENCY OF COLLAPSE (WATER ELEVATION 5.0 CD) (34 TOTAL PAGES)*

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# ANNUAL FREQUENCY OF COLLAPSE - SUMMARY (BASE CASE 2)

| Pier ID | Description | Overall Annual Frequency of Collapse, AF | | | | | | | | | Return Period | % Risk |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inbound | | | | Outbound | | | | Total | | |
| | | 5.0m | 3.3m | 1.6m | -0.1m | 5.0m | 3.3m | 1.6m | -0.1m | | | |
| 1 | North Tower | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | - | 0% |
| 2 | South Tower | 0.00001846 | 0.00001640 | 0.00000551 | 0.00000355 | 0.00008592 | 0.00007349 | 0.00002497 | 0.00001617 | 0.00024446 | 4,091 | 100% |
| **Total for Bridge:** | | 0.00001846 | 0.00001640 | 0.00000551 | 0.00000355 | 0.00008592 | 0.00007349 | 0.00002497 | 0.00001617 | 0.00024446 | **4,091** | **100%** |

**Bridge Type:** Class I
**Minimum Return Period:** 10,000

# VESSEL FLEET ANNUAL TRIP FREQUENCY - DISTRIBUTION

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Annual Number of Trips (N) | | | | | | Existing Total Trips | Annual Number of Trips (N) Distribution for Variable Water Levels | | | | | | | | | | | | | | | | | Existing Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | | Outbound | | | | Inbound | | | | | | | | | Outbound | | | | | | | | |
| | | | | | | | | | | | Loaded | | | | Ballasted | | | | Total | Loaded | | | | Ballasted | | | | Total |
| | | | | Loaded | Ballasted | Total | Loaded | Ballasted | Total | | 5.0m | 3.3m | 1.6m | -0.1m | 5.0m | 3.3m | 1.6m | -0.1m | | 5.0m | 3.3m | 1.6m | -0.1m | 5.0m | 3.3m | 1.6m | -0.1m | | |
| 1 | Ship | Bulk Carrier | 210,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 |
| 2 | Ship | Bulk Carrier | 205,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 |
| 3 | Ship | Bulk Carrier | 185,000 | 0 | 11 | 11 | 0 | 11 | 11 | 22 | 0 | 0 | 0 | 0 | 3 | 2 | 3 | 3 | 11 | 0 | 0 | 0 | 0 | 3 | 2 | 3 | 3 | 11 | 22 |
| 4 | Ship | Bulk Carrier | 180,000 | 1 | 5 | 6 | 3 | 3 | 6 | 12 | 1 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 6 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 6 | 12 |
| 5 | Ship | Bulk Carrier | 175,000 | 0 | 3 | 3 | 2 | 1 | 3 | 6 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 3 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 3 | 6 |
| 6 | Ship | Bulk Carrier | 170,000 | 1 | 2 | 3 | 0 | 3 | 3 | 6 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 6 |
| 7 | Ship | Bulk Carrier | 165,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 |
| 8 | Ship | Bulk Carrier | 155,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| 9 | Ship | Bulk Carrier | 150,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| 10 | Ship | Tanker | 120,000 | 0 | 10 | 10 | 10 | 0 | 10 | 20 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 3 | 10 | 3 | 2 | 2 | 3 | 0 | 0 | 0 | 0 | 10 | 20 |
| 11 | Ship | Bulk Carrier | 120,000 | 0 | 3 | 3 | 2 | 1 | 3 | 6 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 3 | 6 |
| 12 | Ship | Container | 120,000 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 6 |
| 13 | Ship | Tanker | 115,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 4 |
| 14 | Ship | Bulk Carrier | 115,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 |
| 15 | Ship | Container | 115,000 | 8 | 0 | 8 | 8 | 0 | 8 | 16 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 8 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 8 | 16 |
| 16 | Ship | Tanker | 110,000 | 0 | 9 | 9 | 9 | 0 | 9 | 18 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 3 | 9 | 2 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 9 | 18 |
| 17 | Ship | Bulk Carrier | 110,000 | 0 | 3 | 3 | 3 | 0 | 3 | 6 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 3 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 6 |
| 18 | Ship | Container | 110,000 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 5 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 5 | 10 |
| 19 | Ship | Tanker | 105,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 |
| 20 | Ship | Bulk Carrier | 105,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 |
| 21 | Ship | Container | 105,000 | 19 | 0 | 19 | 19 | 0 | 19 | 38 | 5 | 4 | 5 | 5 | 0 | 0 | 0 | 0 | 19 | 5 | 5 | 5 | 4 | 0 | 0 | 0 | 0 | 19 | 38 |
| 22 | Ship | Bulk Carrier | 100,000 | 0 | 8 | 8 | 6 | 2 | 8 | 16 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 8 | 2 | 1 | 1 | 2 | 1 | 0 | 0 | 1 | 8 | 16 |
| 23 | Ship | Container | 100,000 | 42 | 0 | 42 | 42 | 0 | 42 | 84 | 10 | 11 | 11 | 10 | 0 | 0 | 0 | 0 | 42 | 10 | 11 | 11 | 10 | 0 | 0 | 0 | 0 | 42 | 84 |
| 24 | Ship | Bulk Carrier | 95,000 | 0 | 20 | 20 | 11 | 9 | 20 | 40 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 20 | 3 | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 20 | 40 |
| 25 | Ship | Container | 95,000 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 5 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 5 | 10 |
| 26 | Ship | Bulk Carrier | 90,000 | 3 | 15 | 18 | 9 | 9 | 18 | 36 | 1 | 1 | 1 | 0 | 3 | 4 | 4 | 4 | 18 | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 2 | 18 | 36 |
| 27 | Ship | Bulk Carrier | 85,000 | 26 | 157 | 183 | 118 | 65 | 183 | 366 | 7 | 6 | 6 | 7 | 40 | 39 | 39 | 39 | 183 | 30 | 30 | 29 | 29 | 16 | 16 | 16 | 17 | 183 | 366 |
| 28 | Ship | Container | 85,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 4 |
| 29 | Ship | Bulk Carrier | 80,000 | 32 | 133 | 165 | 116 | 49 | 165 | 330 | 8 | 8 | 8 | 8 | 33 | 34 | 33 | 33 | 165 | 29 | 29 | 29 | 29 | 13 | 12 | 12 | 12 | 165 | 330 |
| 30 | Ship | Container | 80,000 | 37 | 0 | 37 | 37 | 0 | 37 | 74 | 9 | 9 | 9 | 10 | 0 | 0 | 0 | 0 | 37 | 10 | 9 | 9 | 9 | 0 | 0 | 0 | 0 | 37 | 74 |
| 31 | Ship | Tanker | 75,000 | 0 | 7 | 7 | 7 | 0 | 7 | 14 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 2 | 7 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 7 | 14 |
| 32 | Ship | Bulk Carrier | 75,000 | 6 | 50 | 56 | 34 | 22 | 56 | 112 | 2 | 2 | 1 | 1 | 12 | 13 | 13 | 12 | 56 | 9 | 9 | 8 | 8 | 5 | 6 | 6 | 5 | 56 | 112 |
| 33 | Ship | Container | 75,000 | 45 | 0 | 45 | 45 | 0 | 45 | 90 | 11 | 11 | 12 | 11 | 0 | 0 | 0 | 0 | 45 | 11 | 11 | 12 | 11 | 0 | 0 | 0 | 0 | 45 | 90 |
| 34 | Ship | Tanker | 70,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 |
| 35 | Ship | Bulk Carrier | 70,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| 36 | Ship | Container | 70,000 | 120 | 0 | 120 | 120 | 0 | 120 | 240 | 30 | 30 | 30 | 30 | 0 | 0 | 0 | 0 | 120 | 30 | 30 | 30 | 30 | 0 | 0 | 0 | 0 | 120 | 240 |
| 37 | Ship | Tanker | 65,000 | 0 | 4 | 4 | 4 | 0 | 4 | 8 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 8 |
| 38 | Ship | Bulk Carrier | 65,000 | 55 | 141 | 196 | 137 | 59 | 196 | 392 | 14 | 14 | 13 | 14 | 35 | 36 | 35 | 35 | 196 | 34 | 35 | 34 | 34 | 15 | 15 | 14 | 15 | 196 | 392 |
| 39 | Ship | Container | 65,000 | 33 | 0 | 33 | 33 | 0 | 33 | 66 | 8 | 8 | 9 | 8 | 0 | 0 | 0 | 0 | 33 | 8 | 8 | 9 | 8 | 0 | 0 | 0 | 0 | 33 | 66 |
| 40 | Ship | Bulk Carrier | 60,000 | 50 | 174 | 224 | 179 | 45 | 224 | 448 | 13 | 12 | 12 | 13 | 43 | 43 | 44 | 44 | 224 | 45 | 45 | 44 | 45 | 11 | 11 | 12 | 11 | 224 | 448 |
| 41 | Ship | General Cargo | 60,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 4 |
| 42 | Ship | Container | 60,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 |
| 43 | Ship | Tanker | 55,000 | 1 | 8 | 9 | 8 | 1 | 9 | 18 | 0 | 1 | 0 | 0 | 2 | 2 | 2 | 2 | 9 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 1 | 9 | 18 |
| 44 | Ship | Bulk Carrier | 55,000 | 7 | 33 | 40 | 27 | 13 | 40 | 80 | 2 | 1 | 2 | 2 | 9 | 8 | 8 | 8 | 40 | 7 | 6 | 7 | 7 | 4 | 3 | 3 | 3 | 40 | 80 |
| 45 | Ship | General Cargo | 55,000 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 2 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 11 | 2 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 11 | 22 |
| 46 | Ship | Tanker | 50,000 | 14 | 31 | 45 | 31 | 14 | 45 | 90 | 4 | 4 | 3 | 3 | 7 | 8 | 8 | 8 | 45 | 8 | 8 | 8 | 7 | 3 | 4 | 4 | 3 | 45 | 90 |
| 47 | Ship | Bulk Carrier | 50,000 | 6 | 13 | 19 | 14 | 5 | 19 | 38 | 1 | 1 | 2 | 2 | 4 | 3 | 3 | 3 | 19 | 4 | 3 | 3 | 4 | 1 | 1 | 1 | 2 | 19 | 38 |
| 48 | Ship | General Cargo | 50,000 | 24 | 24 | 48 | 24 | 24 | 48 | 96 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 48 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 48 | 96 |
| 49 | Ship | Container | 50,000 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 5 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 5 | 10 |

# VESSEL FLEET ANNUAL TRIP FREQUENCY - DISTRIBUTION

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Annual Number of Trips (N) | | | | | | Existing Total Trips | Annual Number of Trips (N) Distribution for Variable Water Levels | | | | | | | | | | | | | | | | Existing Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | | Outbound | | | | Inbound | | | | | | | | | Outbound | | | | | | | | |
| | | | | | | | | | | | Loaded | | | | Ballasted | | | | Total | Loaded | | | | Ballasted | | | | Total | |
| | | | | Loaded | Ballasted | Total | Loaded | Ballasted | Total | | 5.0m | 3.3m | 1.6m | -0.1m | 5.0m | 3.3m | 1.6m | -0.1m | | 5.0m | 3.3m | 1.6m | -0.1m | 5.0m | 3.3m | 1.6m | -0.1m | | |
| 50 | Ship | Tanker | 45,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 4 |
| 51 | Ship | Bulk Carrier | 45,000 | 0 | 4 | 4 | 4 | 0 | 4 | 8 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 8 |
| 52 | Ship | General Cargo | 45,000 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 6 |
| 53 | Ship | Tanker | 40,000 | 2 | 19 | 21 | 19 | 2 | 21 | 42 | 1 | 1 | 0 | 0 | 5 | 5 | 4 | 5 | 21 | 5 | 5 | 4 | 5 | 1 | 1 | 0 | 0 | 21 | 42 |
| 54 | Ship | Bulk Carrier | 40,000 | 22 | 79 | 101 | 77 | 24 | 101 | 202 | 5 | 5 | 6 | 6 | 20 | 19 | 20 | 20 | 101 | 19 | 19 | 20 | 19 | 6 | 6 | 6 | 6 | 101 | 202 |
| 55 | Ship | General Cargo | 40,000 | 7 | 26 | 33 | 26 | 7 | 33 | 66 | 2 | 2 | 2 | 1 | 6 | 7 | 7 | 6 | 33 | 7 | 6 | 6 | 7 | 2 | 1 | 2 | 2 | 33 | 66 |
| 56 | Ship | Tanker | 35,000 | 4 | 8 | 12 | 8 | 4 | 12 | 24 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 12 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 12 | 24 |
| 57 | Ship | Bulk Carrier | 35,000 | 25 | 51 | 76 | 53 | 23 | 76 | 152 | 6 | 6 | 6 | 7 | 13 | 13 | 12 | 13 | 76 | 13 | 14 | 13 | 13 | 5 | 6 | 6 | 6 | 76 | 152 |
| 58 | Ship | General Cargo | 35,000 | 19 | 45 | 64 | 45 | 19 | 64 | 128 | 5 | 5 | 5 | 4 | 11 | 11 | 12 | 11 | 64 | 11 | 11 | 12 | 11 | 5 | 5 | 5 | 4 | 64 | 128 |
| 59 | Ship | Container | 35,000 | 27 | 0 | 27 | 27 | 0 | 27 | 54 | 7 | 7 | 6 | 7 | 0 | 0 | 0 | 0 | 27 | 7 | 7 | 6 | 7 | 0 | 0 | 0 | 0 | 27 | 54 |
| 60 | Ship | Tanker | 30,000 | 1 | 28 | 29 | 28 | 1 | 29 | 58 | 0 | 0 | 1 | 0 | 7 | 7 | 7 | 7 | 29 | 7 | 7 | 7 | 7 | 0 | 0 | 0 | 1 | 29 | 58 |
| 61 | Ship | Bulk Carrier | 30,000 | 9 | 45 | 54 | 40 | 14 | 54 | 108 | 2 | 2 | 2 | 3 | 11 | 11 | 11 | 12 | 54 | 10 | 10 | 10 | 10 | 4 | 4 | 3 | 3 | 54 | 108 |
| 62 | Ship | General Cargo | 30,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 4 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 11 | 18 | 29 | 18 | 11 | 29 | 58 | 3 | 2 | 3 | 3 | 5 | 5 | 4 | 4 | 29 | 5 | 5 | 4 | 4 | 3 | 2 | 3 | 3 | 29 | 58 |
| 64 | Ship | Tanker | 25,000 | 1 | 4 | 5 | 4 | 1 | 5 | 10 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 5 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 5 | 10 |
| 65 | Ship | Bulk Carrier | 25,000 | 1 | 1 | 2 | 1 | 1 | 2 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 4 |
| 66 | Ship | General Cargo | 25,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 4 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 5 | 8 | 13 | 8 | 5 | 13 | 26 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 13 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 13 | 26 |
| 68 | Ship | Tanker | 20,000 | 38 | 17 | 55 | 17 | 38 | 55 | 110 | 9 | 9 | 10 | 10 | 4 | 4 | 4 | 5 | 55 | 4 | 5 | 4 | 4 | 10 | 10 | 9 | 9 | 55 | 110 |
| 69 | Ship | Bulk Carrier | 20,000 | 41 | 6 | 47 | 8 | 39 | 47 | 94 | 11 | 10 | 10 | 10 | 2 | 2 | 1 | 1 | 47 | 2 | 2 | 2 | 2 | 10 | 9 | 10 | 10 | 47 | 94 |
| 70 | Ship | General Cargo | 20,000 | 6 | 0 | 6 | 6 | 0 | 6 | 12 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 6 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 6 | 12 |
| 71 | Ship | Tanker | 15,000 | 0 | 4 | 4 | 4 | 0 | 4 | 8 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 8 |
| 72 | Ship | General Cargo | 15,000 | 5 | 6 | 11 | 6 | 5 | 11 | 22 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 11 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 11 | 22 |
| 73 | Ship | General Cargo | 10,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| 74 | Ship | General Cargo | 5,000 | 10 | 0 | 10 | 10 | 0 | 10 | 20 | 2 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 10 | 3 | 2 | 2 | 3 | 0 | 0 | 0 | 0 | 10 | 20 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 4 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 20 | 0 | 20 | 20 | 0 | 20 | 40 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 20 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 20 | 40 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 75 | 0 | 75 | 75 | 0 | 75 | 150 | 18 | 19 | 19 | 19 | 0 | 0 | 0 | 0 | 75 | 19 | 19 | 18 | 19 | 0 | 0 | 0 | 0 | 75 | 150 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 43 | 0 | 43 | 43 | 0 | 43 | 86 | 11 | 11 | 11 | 10 | 0 | 0 | 0 | 0 | 43 | 11 | 10 | 11 | 11 | 0 | 0 | 0 | 0 | 43 | 86 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 43 | 0 | 43 | 43 | 0 | 43 | 86 | 11 | 11 | 10 | 11 | 0 | 0 | 0 | 0 | 43 | 10 | 11 | 11 | 11 | 0 | 0 | 0 | 0 | 43 | 86 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 10 | 0 | 10 | 10 | 0 | 10 | 20 | 2 | 2 | 3 | 3 | 0 | 0 | 0 | 0 | 10 | 3 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 10 | 20 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 12 | 0 | 12 | 12 | 0 | 12 | 24 | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 12 | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 12 | 24 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 4 | 0 | 4 | 4 | 0 | 4 | 8 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 8 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 6 |
| | | Total Trips: | | 1019 | 1248 | 2267 | 1733 | 534 | 2267 | 4534 | 255 | 255 | 255 | 254 | 312 | 312 | 312 | 312 | 2267 | 434 | 433 | 433 | 433 | 134 | 134 | 133 | 133 | 2267 | 4534 |

## ANNUAL FREQUENCY OF COLLAPSE - SUMMARY (WATER ELEVATION 5.0 CD)

| Pier ID | Description | Ultimate Lateral Capacity, H (MN) | | Overall Annual Frequency of Collapse, AF | | | Return Period | % Risk |
|---|---|---|---|---|---|---|---|---|
| | | Foundation | Tower | Inbound | Outbound | Total | | |
| 1 | North Tower | **33** | **0** | 0.00000000 | 0.00000000 | 0.00000000 | - | 0% |
| 2 | South Tower | **173** | **0** | 0.00001846 | 0.00008592 | 0.00010438 | 9,580 | 100% |
| | | | **Total for Bridge:** | 0.00001846 | 0.00008592 | 0.00010438 | **9,580** | **100%** |

**Bridge Type:** **Class I**

**Minimum Return Period:** **10,000**

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# VESSEL FLEET CHARACTERISTICS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Size (m) | | Vessel Drafts (m) | | | | Vessel Displacement (tonnes) | | Channel Width, C (m) | Centerline Vessel Transit Path to Edge of Channel, $x_C$ (m) | | | | Minimum Design Impact Speed, $V_{min}$ (m/sec) | Standard Deviation, σ (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length Overall, LOA | Beam, B | Operational Loaded, $D_O$ | Ballasted | | | Loaded, $W_L$ | Ballasted, $W_E$ | | Inbound | | Outbound | | | Loaded | Ballasted |
| | | | | | | | Stern, $D_{ES}$ | Bow, $D_{EB}$ | Average, $D_{AVG}$ | | | | Pier 1 | Pier 2 | Pier 1 | Pier 2 | | | |
| 1 | Ship | Bulk Carrier | 210,000 | 300 | 50 | 15.0 | 9.2 | 5.0 | 7.1 | 180,650 | 85,510 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 2 | Ship | Bulk Carrier | 205,000 | 300 | 50 | 15.0 | 10.0 | 5.8 | 7.9 | 180,670 | 95,160 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 3 | Ship | Bulk Carrier | 185,000 | 292 | 45 | 15.0 | 10.2 | 6.1 | 8.2 | 158,000 | 85,850 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 292 | 292 |
| 4 | Ship | Bulk Carrier | 180,000 | 292 | 45 | 12.3 | 10.4 | 6.3 | 8.4 | 129,390 | 87,840 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 292 | 292 |
| 5 | Ship | Bulk Carrier | 175,000 | 289 | 45 | 12.6 | 9.5 | 5.4 | 7.5 | 130,940 | 77,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 289 | 289 |
| 6 | Ship | Bulk Carrier | 170,000 | 288 | 44 | 14.5 | 10.1 | 6.0 | 8.1 | 146,610 | 81,390 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 288 | 288 |
| 7 | Ship | Bulk Carrier | 165,000 | 288 | 44 | 15.0 | 10.0 | 5.9 | 8.0 | 151,460 | 80,280 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 288 | 288 |
| 8 | Ship | Bulk Carrier | 155,000 | 273 | 46 | 15.0 | 9.6 | 5.7 | 7.7 | 149,850 | 76,430 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 273 | 273 |
| 9 | Ship | Bulk Carrier | 150,000 | 269 | 43 | 15.0 | 10.0 | 6.2 | 8.1 | 137,740 | 74,380 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 269 | 269 |
| 10 | Ship | Tanker | 120,000 | 250 | 44 | 11.9 | 8.2 | 4.7 | 6.5 | 101,270 | 54,890 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 250 |
| 11 | Ship | Bulk Carrier | 120,000 | 254 | 43 | 14.5 | 7.6 | 4.0 | 5.8 | 124,980 | 50,000 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 254 | 254 |
| 12 | Ship | Container | 120,000 | 324 | 48 | 12.6 | 12.6 | 12.6 | 12.6 | 120,230 | 120,230 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 324 | 324 |
| 13 | Ship | Tanker | 115,000 | 250 | 44 | 11.9 | 9.3 | 5.8 | 7.6 | 101,120 | 64,160 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 250 |
| 14 | Ship | Bulk Carrier | 115,000 | 254 | 43 | 14.7 | 8.1 | 4.5 | 6.3 | 126,740 | 54,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 254 | 254 |
| 15 | Ship | Container | 115,000 | 300 | 48 | 11.9 | 11.9 | 11.9 | 11.9 | 105,070 | 105,070 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 16 | Ship | Tanker | 110,000 | 240 | 44 | 11.8 | 8.3 | 4.9 | 6.6 | 95,920 | 53,650 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 240 |
| 17 | Ship | Bulk Carrier | 110,000 | 255 | 43 | 12.3 | 8.2 | 4.6 | 6.4 | 106,510 | 55,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 255 | 255 |
| 18 | Ship | Container | 110,000 | 334 | 43 | 12.3 | 12.3 | 12.3 | 12.3 | 108,560 | 108,560 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 334 | 334 |
| 19 | Ship | Tanker | 105,000 | 244 | 42 | 13.0 | 8.4 | 5.0 | 6.7 | 102,480 | 52,820 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 244 |
| 20 | Ship | Bulk Carrier | 105,000 | 235 | 43 | 14.0 | 8.3 | 5.0 | 6.7 | 111,780 | 53,100 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 235 | 235 |
| 21 | Ship | Container | 105,000 | 335 | 43 | 12.6 | 12.6 | 12.6 | 12.6 | 111,550 | 111,550 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 335 | 335 |
| 22 | Ship | Bulk Carrier | 100,000 | 235 | 38 | 13.5 | 7.8 | 4.5 | 6.2 | 95,280 | 43,410 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 235 | 235 |
| 23 | Ship | Container | 100,000 | 338 | 46 | 12.8 | 12.8 | 12.8 | 12.8 | 122,370 | 122,370 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 338 | 338 |
| 24 | Ship | Bulk Carrier | 95,000 | 229 | 38 | 12.8 | 8.9 | 5.7 | 7.3 | 88,020 | 50,200 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 25 | Ship | Container | 95,000 | 320 | 46 | 13.6 | 13.6 | 13.6 | 13.6 | 122,750 | 122,750 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 320 | 320 |
| 26 | Ship | Bulk Carrier | 90,000 | 229 | 38 | 12.6 | 8.5 | 5.3 | 6.9 | 86,760 | 47,510 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 27 | Ship | Bulk Carrier | 85,000 | 229 | 32 | 12.7 | 8.2 | 5.0 | 6.6 | 73,730 | 38,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 28 | Ship | Container | 85,000 | 300 | 40 | 12.0 | 12.0 | 12.0 | 12.0 | 88,300 | 88,300 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 300 | 300 |
| 29 | Ship | Bulk Carrier | 80,000 | 225 | 32 | 12.3 | 7.7 | 4.5 | 6.1 | 70,180 | 34,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 225 | 225 |
| 30 | Ship | Container | 80,000 | 300 | 42 | 12.1 | 12.1 | 12.1 | 12.1 | 93,480 | 93,480 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 300 | 300 |
| 31 | Ship | Tanker | 75,000 | 228 | 34 | 11.3 | 8.3 | 5.1 | 6.7 | 66,730 | 39,570 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 228 |
| 32 | Ship | Bulk Carrier | 75,000 | 225 | 32 | 12.1 | 7.8 | 4.6 | 6.2 | 68,640 | 35,180 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 225 | 225 |
| 33 | Ship | Container | 75,000 | 293 | 40 | 12.3 | 12.3 | 12.3 | 12.3 | 88,600 | 88,600 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 293 | 293 |
| 34 | Ship | Tanker | 70,000 | 228 | 32 | 11.0 | 7.4 | 4.2 | 5.8 | 62,330 | 32,870 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 228 |
| 35 | Ship | Bulk Carrier | 70,000 | 199 | 36 | 12.2 | 6.5 | 3.7 | 5.1 | 68,720 | 28,730 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 199 | 199 |
| 36 | Ship | Container | 70,000 | 285 | 40 | 11.6 | 11.6 | 11.6 | 11.6 | 81,160 | 81,160 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 37 | Ship | Tanker | 65,000 | 214 | 32 | 10.9 | 7.5 | 4.5 | 6.0 | 57,520 | 31,660 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 73 | 214 |
| 38 | Ship | Bulk Carrier | 65,000 | 200 | 32 | 11.8 | 7.3 | 4.5 | 5.9 | 58,740 | 29,370 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 39 | Ship | Container | 65,000 | 285 | 38 | 12.2 | 12.2 | 12.2 | 12.2 | 79,180 | 79,180 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 40 | Ship | Bulk Carrier | 60,000 | 190 | 32 | 11.6 | 7.2 | 4.5 | 5.9 | 54,690 | 27,580 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 190 | 190 |
| 41 | Ship | General Cargo | 60,000 | 200 | 33 | 11.0 | 11.0 | 11.0 | 11.0 | 49,840 | 49,840 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 42 | Ship | Container | 60,000 | 268 | 35 | 12.0 | 12.0 | 12.0 | 12.0 | 75,320 | 75,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 268 | 268 |
| 43 | Ship | Tanker | 55,000 | 184 | 32 | 11.4 | 8.3 | 5.7 | 7.0 | 51,250 | 31,470 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 184 |
| 44 | Ship | Bulk Carrier | 55,000 | 190 | 32 | 11.0 | 7.1 | 4.4 | 5.8 | 51,680 | 27,020 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 190 | 190 |
| 45 | Ship | General Cargo | 55,000 | 200 | 32 | 8.2 | 8.2 | 8.2 | 8.2 | 36,030 | 36,030 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 46 | Ship | Tanker | 50,000 | 183 | 32 | 10.6 | 8.2 | 5.6 | 6.9 | 47,500 | 30,920 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 183 |
| 47 | Ship | Bulk Carrier | 50,000 | 192 | 32 | 10.1 | 7.4 | 4.7 | 6.1 | 47,810 | 28,640 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 192 | 192 |
| 48 | Ship | General Cargo | 50,000 | 200 | 31 | 10.9 | 10.9 | 10.9 | 10.9 | 46,390 | 46,390 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 49 | Ship | Container | 50,000 | 259 | 32 | 11.3 | 11.3 | 11.3 | 11.3 | 59,010 | 59,010 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 259 | 259 |

# VESSEL FLEET CHARACTERISTICS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Size (m) | | Vessel Drafts (m) | | | | Vessel Displacement (tonnes) | | Channel Width, C (m) | Centerline Vessel Transit Path to Edge of Channel, $x_C$ (m) | | | | Minimum Design Impact Speed, $V_{min}$ (m/sec) | Standard Deviation, σ (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length Overall, LOA | Beam, B | Operational Loaded, $D_O$ | Ballasted | | | Loaded, $W_L$ | Ballasted, $W_E$ | | Inbound | | Outbound | | | Loaded | Ballasted |
| | | | | | | | Stern, $D_{ES}$ | Bow, $D_{EB}$ | Average, $D_{AVG}$ | | | | Pier 1 | Pier 2 | Pier 1 | Pier 2 | | | |
| 50 | Ship | Tanker | 45,000 | 181 | 32 | 10.3 | 8.6 | 6.1 | 7.4 | 45,340 | 32,350 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 181 |
| 51 | Ship | Bulk Carrier | 45,000 | 188 | 29 | 10.3 | 6.9 | 4.3 | 5.6 | 43,080 | 23,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 188 | 188 |
| 52 | Ship | General Cargo | 45,000 | 187 | 29 | 10.1 | 10.1 | 10.1 | 10.1 | 37,670 | 37,670 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 187 | 187 |
| 53 | Ship | Tanker | 40,000 | 179 | 28 | 10.1 | 7.5 | 5.0 | 6.3 | 38,430 | 23,780 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 70 | 179 |
| 54 | Ship | Bulk Carrier | 40,000 | 180 | 30 | 9.6 | 6.6 | 4.1 | 5.4 | 39,540 | 22,040 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 55 | Ship | General Cargo | 40,000 | 180 | 30 | 9.6 | 9.6 | 9.6 | 9.6 | 35,590 | 35,590 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 56 | Ship | Tanker | 35,000 | 173 | 27 | 10.2 | 7.3 | 4.9 | 6.1 | 35,600 | 21,290 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 173 | 173 |
| 57 | Ship | Bulk Carrier | 35,000 | 180 | 30 | 9.3 | 6.4 | 3.9 | 5.2 | 37,960 | 21,020 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 58 | Ship | General Cargo | 35,000 | 180 | 28 | 6.7 | 6.7 | 6.7 | 6.7 | 23,250 | 23,250 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 59 | Ship | Container | 35,000 | 209 | 30 | 9.3 | 9.3 | 9.3 | 9.3 | 34,600 | 34,600 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 209 | 209 |
| 60 | Ship | Tanker | 30,000 | 159 | 27 | 9.2 | 6.5 | 4.3 | 5.4 | 29,160 | 17,120 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 159 | 159 |
| 61 | Ship | Bulk Carrier | 30,000 | 170 | 27 | 9.6 | 5.8 | 3.4 | 4.6 | 33,110 | 15,870 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 170 | 170 |
| 62 | Ship | General Cargo | 30,000 | 166 | 27 | 9.7 | 9.7 | 9.7 | 9.7 | 29,990 | 29,990 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 166 | 166 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 210 | 23 | 9.3 | 5.0 | 5.0 | 5.0 | 32,470 | 17,460 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 210 | 210 |
| 64 | Ship | Tanker | 25,000 | 146 | 24 | 9.2 | 6.5 | 4.5 | 5.5 | 22,970 | 13,740 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 146 | 146 |
| 65 | Ship | Bulk Carrier | 25,000 | 154 | 26 | 7.7 | 6.8 | 4.6 | 5.7 | 23,000 | 17,030 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 154 | 154 |
| 66 | Ship | General Cargo | 25,000 | 154 | 26 | 8.1 | 8.1 | 8.1 | 8.1 | 22,150 | 22,150 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 154 | 154 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 184 | 24 | 8.3 | 5.0 | 5.0 | 5.0 | 26,090 | 15,720 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 184 | 184 |
| 68 | Ship | Tanker | 20,000 | 145 | 24 | 8.7 | 6.1 | 4.1 | 5.1 | 20,880 | 12,240 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 145 | 145 |
| 69 | Ship | Bulk Carrier | 20,000 | 144 | 23 | 7.7 | 6.1 | 4.1 | 5.1 | 18,790 | 12,450 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 144 | 144 |
| 70 | Ship | General Cargo | 20,000 | 161 | 25 | 8.5 | 8.5 | 8.5 | 8.5 | 23,000 | 23,000 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 161 | 161 |
| 71 | Ship | Tanker | 15,000 | 127 | 20 | 8.1 | 6.3 | 4.5 | 5.4 | 14,280 | 9,520 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 127 | 127 |
| 72 | Ship | General Cargo | 15,000 | 138 | 21 | 7.2 | 7.2 | 7.2 | 7.2 | 14,100 | 14,100 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 138 | 138 |
| 73 | Ship | General Cargo | 10,000 | 118 | 16 | 4.5 | 4.5 | 4.5 | 4.5 | 5,810 | 5,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 118 | 118 |
| 74 | Ship | General Cargo | 5,000 | 117 | 20 | 4.7 | 4.7 | 4.7 | 4.7 | 7,740 | 7,740 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 117 | 117 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 317 | 37 | 8.3 | 8.3 | 8.3 | 8.3 | 61,410 | 61,410 | 142.0 | 93.5 | 48.5 | 57.0 | 85.0 | 2.57 | 317 | 317 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 290 | 36 | 8.5 | 8.5 | 8.5 | 8.5 | 53,680 | 53,680 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 290 | 290 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 294 | 32 | 8.6 | 8.6 | 8.6 | 8.6 | 49,330 | 49,330 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 294 | 294 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 285 | 32 | 8.0 | 8.0 | 8.0 | 8.0 | 44,490 | 44,490 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 240 | 32 | 8.1 | 8.1 | 8.1 | 8.1 | 35,120 | 35,120 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 240 | 240 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 220 | 31 | 7.7 | 7.7 | 7.7 | 7.7 | 29,250 | 29,250 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 220 | 220 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 186 | 25 | 6.1 | 6.1 | 6.1 | 6.1 | 15,810 | 15,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 186 | 186 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 142 | 18 | 4.9 | 4.9 | 4.9 | 4.9 | 7,050 | 7,050 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 142 | 142 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 103 | 15 | 4.1 | 4.1 | 4.1 | 4.1 | 3,660 | 3,660 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 103 | 103 |

**Notes:**

Weight of Water ($W_W$) = **0.9854** $m^3$/tonne (used to determine ship loaded/ballasted displacement tonnage based on approximate salinity of water in Vancouver Harbor)

# VESSEL FLEET ANNUAL TRIP FREQUENCY

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Annual Number of Trips (N) | | | | | | Existing Total Trips | Growth Factor [1] | Future Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | | Outbound | | | | | |
| | | | | Loaded | Ballasted | Total | Loaded | Ballasted | Total | | | |
| 1 | Ship | Bulk Carrier | 210,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 1.28 | 3 |
| 2 | Ship | Bulk Carrier | 205,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 3 | Ship | Bulk Carrier | 185,000 | 0 | 3 | 3 | 0 | 3 | 3 | 6 | 1.28 | 8 |
| 4 | Ship | Bulk Carrier | 180,000 | 1 | 1 | 2 | 1 | 0 | 1 | 3 | 1.28 | 4 |
| 5 | Ship | Bulk Carrier | 175,000 | 0 | 1 | 1 | 1 | 1 | 2 | 3 | 1.28 | 4 |
| 6 | Ship | Bulk Carrier | 170,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 7 | Ship | Bulk Carrier | 165,000 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1.28 | 1 |
| 8 | Ship | Bulk Carrier | 155,000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 9 | Ship | Bulk Carrier | 150,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 10 | Ship | Tanker | 120,000 | 0 | 2 | 2 | 3 | 0 | 3 | 5 | 10.20 | 51 |
| 11 | Ship | Bulk Carrier | 120,000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 12 | Ship | Container | 120,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 13 | Ship | Tanker | 115,000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 10.20 | 10 |
| 14 | Ship | Bulk Carrier | 115,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 15 | Ship | Container | 115,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 16 | Ship | Tanker | 110,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 10.20 | 41 |
| 17 | Ship | Bulk Carrier | 110,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 18 | Ship | Container | 110,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 19 | Ship | Tanker | 105,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10.20 | 0 |
| 20 | Ship | Bulk Carrier | 105,000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 21 | Ship | Container | 105,000 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1.28 | 13 |
| 22 | Ship | Bulk Carrier | 100,000 | 0 | 2 | 2 | 2 | 1 | 3 | 5 | 1.28 | 6 |
| 23 | Ship | Container | 100,000 | 10 | 0 | 10 | 10 | 0 | 10 | 20 | 1.28 | 26 |
| 24 | Ship | Bulk Carrier | 95,000 | 0 | 5 | 5 | 3 | 2 | 5 | 10 | 1.28 | 13 |
| 25 | Ship | Container | 95,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 26 | Ship | Bulk Carrier | 90,000 | 1 | 3 | 4 | 2 | 2 | 4 | 8 | 1.28 | 10 |
| 27 | Ship | Bulk Carrier | 85,000 | 7 | 40 | 47 | 30 | 16 | 46 | 93 | 1.28 | 119 |
| 28 | Ship | Container | 85,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 29 | Ship | Bulk Carrier | 80,000 | 8 | 33 | 41 | 29 | 13 | 42 | 83 | 1.28 | 106 |
| 30 | Ship | Container | 80,000 | 9 | 0 | 9 | 10 | 0 | 10 | 19 | 1.28 | 24 |
| 31 | Ship | Tanker | 75,000 | 0 | 2 | 2 | 1 | 0 | 1 | 3 | 1.64 | 5 |
| 32 | Ship | Bulk Carrier | 75,000 | 2 | 12 | 14 | 9 | 5 | 14 | 28 | 1.28 | 36 |
| 33 | Ship | Container | 75,000 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 1.28 | 28 |
| 34 | Ship | Tanker | 70,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.64 | 0 |
| 35 | Ship | Bulk Carrier | 70,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 36 | Ship | Container | 70,000 | 30 | 0 | 30 | 30 | 0 | 30 | 60 | 1.28 | 77 |
| 37 | Ship | Tanker | 65,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 38 | Ship | Bulk Carrier | 65,000 | 14 | 35 | 49 | 34 | 15 | 49 | 98 | 1.28 | 125 |
| 39 | Ship | Container | 65,000 | 8 | 0 | 8 | 8 | 0 | 8 | 16 | 1.28 | 20 |
| 40 | Ship | Bulk Carrier | 60,000 | 13 | 43 | 56 | 45 | 11 | 56 | 112 | 1.28 | 143 |
| 41 | Ship | General Cargo | 60,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 42 | Ship | Container | 60,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 43 | Ship | Tanker | 55,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 1.64 | 7 |
| 44 | Ship | Bulk Carrier | 55,000 | 2 | 9 | 11 | 7 | 4 | 11 | 22 | 1.28 | 28 |
| 45 | Ship | General Cargo | 55,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 46 | Ship | Tanker | 50,000 | 4 | 7 | 11 | 8 | 3 | 11 | 22 | 1.64 | 36 |
| 47 | Ship | Bulk Carrier | 50,000 | 1 | 4 | 5 | 4 | 1 | 5 | 10 | 1.28 | 13 |
| 48 | Ship | General Cargo | 50,000 | 6 | 6 | 12 | 6 | 6 | 12 | 24 | 1.28 | 31 |
| 49 | Ship | Container | 50,000 | 2 | 0 | 2 | 1 | 0 | 1 | 3 | 1.28 | 4 |

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# VESSEL FLEET ANNUAL TRIP FREQUENCY

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Annual Number of Trips (N) | | | | | | Existing Total Trips | Growth Factor [1] | Future Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | | Outbound | | | | | |
| | | | | Loaded | Ballasted | Total | Loaded | Ballasted | Total | | | |
| 50 | Ship | Tanker | 45,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.64 | 0 |
| 51 | Ship | Bulk Carrier | 45,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 52 | Ship | General Cargo | 45,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 53 | Ship | Tanker | 40,000 | 1 | 5 | 6 | 5 | 1 | 6 | 12 | 1.64 | 20 |
| 54 | Ship | Bulk Carrier | 40,000 | 5 | 20 | 25 | 19 | 6 | 25 | 50 | 1.28 | 64 |
| 55 | Ship | General Cargo | 40,000 | 2 | 6 | 8 | 7 | 2 | 9 | 17 | 1.28 | 22 |
| 56 | Ship | Tanker | 35,000 | 1 | 2 | 3 | 2 | 1 | 3 | 6 | 1.64 | 10 |
| 57 | Ship | Bulk Carrier | 35,000 | 6 | 13 | 19 | 13 | 5 | 18 | 37 | 1.28 | 47 |
| 58 | Ship | General Cargo | 35,000 | 5 | 11 | 16 | 11 | 5 | 16 | 32 | 1.28 | 41 |
| 59 | Ship | Container | 35,000 | 7 | 0 | 7 | 7 | 0 | 7 | 14 | 1.28 | 18 |
| 60 | Ship | Tanker | 30,000 | 0 | 7 | 7 | 7 | 0 | 7 | 14 | 1.64 | 23 |
| 61 | Ship | Bulk Carrier | 30,000 | 2 | 11 | 13 | 10 | 4 | 14 | 27 | 1.28 | 35 |
| 62 | Ship | General Cargo | 30,000 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 3 | 5 | 8 | 5 | 3 | 8 | 16 | 1.28 | 20 |
| 64 | Ship | Tanker | 25,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 65 | Ship | Bulk Carrier | 25,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 66 | Ship | General Cargo | 25,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 1 | 2 | 3 | 2 | 1 | 3 | 6 | 1.28 | 8 |
| 68 | Ship | Tanker | 20,000 | 9 | 4 | 13 | 4 | 10 | 14 | 27 | 1.64 | 44 |
| 69 | Ship | Bulk Carrier | 20,000 | 11 | 2 | 13 | 2 | 10 | 12 | 25 | 1.28 | 32 |
| 70 | Ship | General Cargo | 20,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 71 | Ship | Tanker | 15,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 72 | Ship | General Cargo | 15,000 | 1 | 1 | 2 | 2 | 1 | 3 | 5 | 1.28 | 6 |
| 73 | Ship | General Cargo | 10,000 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 74 | Ship | General Cargo | 5,000 | 2 | 0 | 2 | 3 | 0 | 3 | 5 | 1.28 | 6 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1.28 | 13 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 18 | 0 | 18 | 19 | 0 | 19 | 37 | 1.28 | 47 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 1.28 | 28 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 11 | 0 | 11 | 10 | 0 | 10 | 21 | 1.28 | 27 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 2 | 0 | 2 | 3 | 0 | 3 | 5 | 1.28 | 6 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| | | | **Total Trips:** | 255 | 312 | 567 | 434 | 134 | 568 | 1135 | | 1577 |

**Notes:**

[1] As part of the risk analysis, vessel trips will include future growth in the waterway that are projected to the mid-point of the remaining design life (assumed 50 years) of the structure. This equates to growth rates per year as follows for a 25-year projection. GF = $(1+\text{PERCENT}/100)^{25}$

- Aframax Tankers (DWT greater than 100,000 tonnes) = 9.735%
- All Other Tankers = 2.0%
- All Other Vessels = 1.0%

# VESSEL FLEET TRANSIT SPEEDS IN MAIN CHANNEL

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Transit Speeds (knots) | | | | Vessel Transit Speeds (m/sec) [1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | Outbound | | Inbound | | Outbound | |
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted |
| 1 | Ship | Bulk Carrier | 210,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 2 | Ship | Bulk Carrier | 205,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 3 | Ship | Bulk Carrier | 185,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 4 | Ship | Bulk Carrier | 180,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 5 | Ship | Bulk Carrier | 175,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 6 | Ship | Bulk Carrier | 170,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 7 | Ship | Bulk Carrier | 165,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 8 | Ship | Bulk Carrier | 155,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 9 | Ship | Bulk Carrier | 150,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 10 | Ship | Tanker | 120,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 11 | Ship | Bulk Carrier | 120,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 12 | Ship | Container | 120,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 13 | Ship | Tanker | 115,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 14 | Ship | Bulk Carrier | 115,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 15 | Ship | Container | 115,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 16 | Ship | Tanker | 110,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 17 | Ship | Bulk Carrier | 110,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 18 | Ship | Container | 110,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 19 | Ship | Tanker | 105,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 20 | Ship | Bulk Carrier | 105,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 21 | Ship | Container | 105,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 22 | Ship | Bulk Carrier | 100,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 23 | Ship | Container | 100,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 24 | Ship | Bulk Carrier | 95,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 25 | Ship | Container | 95,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 26 | Ship | Bulk Carrier | 90,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 27 | Ship | Bulk Carrier | 85,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 28 | Ship | Container | 85,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 29 | Ship | Bulk Carrier | 80,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 30 | Ship | Container | 80,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 31 | Ship | Tanker | 75,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 32 | Ship | Bulk Carrier | 75,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 33 | Ship | Container | 75,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 34 | Ship | Tanker | 70,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 35 | Ship | Bulk Carrier | 70,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 36 | Ship | Container | 70,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 37 | Ship | Tanker | 65,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 38 | Ship | Bulk Carrier | 65,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 39 | Ship | Container | 65,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 40 | Ship | Bulk Carrier | 60,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 41 | Ship | General Cargo | 60,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 42 | Ship | Container | 60,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 43 | Ship | Tanker | 55,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 44 | Ship | Bulk Carrier | 55,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 45 | Ship | General Cargo | 55,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 46 | Ship | Tanker | 50,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 47 | Ship | Bulk Carrier | 50,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 48 | Ship | General Cargo | 50,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 49 | Ship | Container | 50,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |

# VESSEL FLEET TRANSIT SPEEDS IN MAIN CHANNEL

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Transit Speeds (knots) | | | | Vessel Transit Speeds (m/sec) [1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | Outbound | | Inbound | | Outbound | |
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted |
| 50 | Ship | Tanker | 45,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 51 | Ship | Bulk Carrier | 45,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 52 | Ship | General Cargo | 45,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 53 | Ship | Tanker | 40,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 54 | Ship | Bulk Carrier | 40,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 55 | Ship | General Cargo | 40,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 56 | Ship | Tanker | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 57 | Ship | Bulk Carrier | 35,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 58 | Ship | General Cargo | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 59 | Ship | Container | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 60 | Ship | Tanker | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 61 | Ship | Bulk Carrier | 30,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 62 | Ship | General Cargo | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 64 | Ship | Tanker | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 65 | Ship | Bulk Carrier | 25,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 66 | Ship | General Cargo | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 68 | Ship | Tanker | 20,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 69 | Ship | Bulk Carrier | 20,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 70 | Ship | General Cargo | 20,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 71 | Ship | Tanker | 15,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 72 | Ship | General Cargo | 15,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 73 | Ship | General Cargo | 10,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 74 | Ship | General Cargo | 5,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |

**Notes:**

[1] Conversion (knot to m/sec) = 0.51 (convert vessel transit speeds from knots to meters/second for use in risk assessment equations)

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)



# ABERRANCY BASE RATE COMPUTATIONS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Code Recommended Aberrancy Base Rate, BR | Vessel Traffic Service, VTS | Electronic Chart Display & Information System, ECDIS | Other Navigation Aids | Port Control State, PCS | Pilotage 1 Pilot | Pilotage 2 Pilots (MRA-2) | | Daytime Only Transit Restrictions (MRA-2) | Visibility Restrictions (MRA-2) | Cruise Ship Considerations | Adjusted Aberrancy Base Rate, BR [1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Loaded | Ballasted | | | | Loaded | Ballasted |
| 1 | Ship | Bulk Carrier | 210,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 2 | Ship | Bulk Carrier | 205,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 3 | Ship | Bulk Carrier | 185,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 4 | Ship | Bulk Carrier | 180,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 5 | Ship | Bulk Carrier | 175,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 6 | Ship | Bulk Carrier | 170,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 7 | Ship | Bulk Carrier | 165,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 8 | Ship | Bulk Carrier | 155,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 9 | Ship | Bulk Carrier | 150,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 10 | Ship | Tanker | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 11 | Ship | Bulk Carrier | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 12 | Ship | Container | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 13 | Ship | Tanker | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 14 | Ship | Bulk Carrier | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 15 | Ship | Container | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 16 | Ship | Tanker | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 17 | Ship | Bulk Carrier | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 18 | Ship | Container | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 19 | Ship | Tanker | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 20 | Ship | Bulk Carrier | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 21 | Ship | Container | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 22 | Ship | Bulk Carrier | 100,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 23 | Ship | Container | 100,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 24 | Ship | Bulk Carrier | 95,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 25 | Ship | Container | 95,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 26 | Ship | Bulk Carrier | 90,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 27 | Ship | Bulk Carrier | 85,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 28 | Ship | Container | 85,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 29 | Ship | Bulk Carrier | 80,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 30 | Ship | Container | 80,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 31 | Ship | Tanker | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 32 | Ship | Bulk Carrier | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 33 | Ship | Container | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 34 | Ship | Tanker | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 35 | Ship | Bulk Carrier | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 36 | Ship | Container | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 37 | Ship | Tanker | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 38 | Ship | Bulk Carrier | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 39 | Ship | Container | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 40 | Ship | Bulk Carrier | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 41 | Ship | General Cargo | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 42 | Ship | Container | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 43 | Ship | Tanker | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 44 | Ship | Bulk Carrier | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 45 | Ship | General Cargo | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 46 | Ship | Tanker | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 47 | Ship | Bulk Carrier | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 48 | Ship | General Cargo | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 49 | Ship | Container | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |

# ABERRANCY BASE RATE COMPUTATIONS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Code Recommended Aberrancy Base Rate, BR | Vessel Traffic Service, VTS | Electronic Chart Display & Information System, ECDIS | Other Navigation Aids | Port Control State, PCS | Pilotage 1 Pilot | Pilotage 2 Pilots (MRA-2) | | Daytime Only Transit Restrictions (MRA-2) | Visibility Restrictions (MRA-2) | Cruise Ship Considerations | Adjusted Aberrancy Base Rate, BR [1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Loaded | Ballasted | | | | Loaded | Ballasted |
| 50 | Ship | Tanker | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 51 | Ship | Bulk Carrier | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 52 | Ship | General Cargo | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 53 | Ship | Tanker | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 54 | Ship | Bulk Carrier | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 55 | Ship | General Cargo | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 56 | Ship | Tanker | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 57 | Ship | Bulk Carrier | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 58 | Ship | General Cargo | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 59 | Ship | Container | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 60 | Ship | Tanker | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 61 | Ship | Bulk Carrier | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 62 | Ship | General Cargo | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 64 | Ship | Tanker | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 65 | Ship | Bulk Carrier | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 66 | Ship | General Cargo | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 68 | Ship | Tanker | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 69 | Ship | Bulk Carrier | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 70 | Ship | General Cargo | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 71 | Ship | Tanker | 15,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 72 | Ship | General Cargo | 15,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 73 | Ship | General Cargo | 10,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 74 | Ship | General Cargo | 5,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |

**Notes:**

[1] Adjustments to the aberrancy Base Rate (BR) due to waterway current restrictions are accounted for elsewhere in the vessel collision risk analysis (refer to correction factors $R_C$ and $R_{XC}$ for the Probability of Aberrancy at each transit leg).

# MISCELLANEOUS INFORMATION

## CHANNEL CHARACTERISTICS

| | | |
|---|---|---|
| Waterway Current Speed ($V_{min}$) = | **2.57** | m/sec |
| Water Elevation = | **5.00** | m (based on Chart Datum) |
| Sea Level Rise Adjustment = | **0.10** | m |
| Soft Soil Allowance = | **2.00** | m (assumed depth that vessels can "plow" through soft bottom material or "ride up" on underlying rock) |

## AVAILABLE WATER DEPTH AT PIERS

| Pier ID | Description | Mudline Elevation (m) [1] | | Water Elevation (m) | Soft Soil Allowance (m) | Design Water Depth (m) | |
|---|---|---|---|---|---|---|---|
| | | Inbound | Outbound | | | Inbound | Outbound |
| **1** | **North Tower** | **5.00** | **5.00** | 5.10 | 2.00 | 2.10 | 2.10 |
| **2** | **South Tower** | **-7.00** | **-7.00** | 5.10 | 2.00 | 14.10 | 14.10 |

**Notes:**

[1] Mudline elevation is based on Chart Datum (CD) and was obtained from Nautical Chart 3493

## PROBABILITY OF ABERRANCY VARIABLES FOR EACH VESSEL TRANSIT PATH

| Leg ID | Waterway Region for Bridge Location | Angle of Channel Turn, θ (deg) [1] | Correction Factor, $R_B$ | Current Angle to Vessel Path (deg) [2] | Parallel Current, $V_C$ (m/sec) | Perpendicular Current, $V_{XC}$ (m/sec) | Correction Factor, $R_C$ | Correction Factor, $R_{XC}$ | Vessel Traffic Density | Correction Factor, $R_D$ | Summation ($R_B$*$R_C$*$R_{XC}$*$R_D$) | Aberrancy Distribution [3] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Inbound | Outbound |
| **1** | **Transition** | **44.4795** | 1.4942 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 2.2622 | **0.16** | **N/A** |
| **2** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.40** | **N/A** |
| **3** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.22** | **N/A** |
| **4** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.22** | **N/A** |
| **5** | **Transition** | **28.0177** | 1.3113 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 1.9853 | **N/A** | **0.50** |
| **6** | **Straight** | **0.0000** | 1.0000 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 1.5140 | **N/A** | **0.50** |

**Notes:**

[1] Angle of the turn region in accordance with information shown on Nautical Chart 3493, AIS transit data near the bridge, and CAN/CSA S6-14 Figure A3.3.1

[2] The angle between the water current direction and each channel transition leg

[3] Distribution of the Probability of Aberrancy for each channel transition leg is established as a ratio of the length of each leg to the overall length being considered (approximately 1 nautical mile or 2000m)

## GEOMETRIC PROBABILITY DISTANCES FOR NORMAL DISTRIBUTION

| Pier ID | Description | Leg 1 [1] | | | Leg 2 [1] | | | Leg 3 [1] | | | Leg 4 [1] | | | Leg 5 [1] | | | Leg 6 [1] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) |
| 1 | North Tower | **328.75** | 342.54 | **356.34** | **32.88** | 44.83 | **56.78** | **138.33** | 149.19 | **160.06** | **245.78** | 254.19 | **262.59** | **212.19** | 219.89 | **227.60** | **212.19** | 219.89 | **227.60** |
| 2 | South Tower | **684.04** | 701.58 | **719.11** | **356.33** | 371.76 | **387.18** | **274.04** | 288.34 | **302.64** | **197.61** | 209.61 | **221.61** | **239.38** | 250.07 | **260.76** | **239.38** | 250.07 | **260.76** |

**Notes:**

[1] Perpendicular distances at each channel transition leg from the centerline of vessel transit path to the bridge element being considered. Distance "x" is from the centerline of vessel transit path to the centerline of bridge element. Distance "$x_1$" (scaled from CADD drawing) is from the centerline of vessel transit path to the closest edge of the bridge element. Distance "$x_2$" (scaled from CADD drawing) is from the centerline of vessel transit path to the farthest edge of the bridge element.

## PROTECTION FACTOR

| Pier ID | Description | Leg 1 | | Leg 2 | | Leg 3 | | Leg 4 | | Leg 5 | | Leg 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound |
| 1 | North Tower | **0.62** | **N/A** | **0.54** | **N/A** | **0.43** | **N/A** | **0.33** | **N/A** | **N/A** | **0.18** | **N/A** | **0.18** |
| 2 | South Tower | **0.003** | **N/A** | **0.01** | **N/A** | **0.02** | **N/A** | **0.04** | **N/A** | **N/A** | **0.14** | **N/A** | **0.14** |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053804 | 0.053804 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053804 | 0.053804 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049883 | 0.049883 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049883 | 0.049883 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049686 | 0.049686 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048933 | 0.048933 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048933 | 0.048933 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049023 | 0.049023 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046613 | 0.046613 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000027 | 0.044813 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044769 | 0.044769 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053234 | 0.053234 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000027 | 0.044813 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044769 | 0.044769 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.052415 | 0.052415 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000023 | 0.043133 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044909 | 0.044909 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049831 | 0.049831 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000023 | 0.042606 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.041590 | 0.041590 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049838 | 0.049838 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.038622 | 0.038622 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.051971 | 0.051971 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.037482 | 0.037482 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.051743 | 0.051743 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.037482 | 0.037482 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.034028 | 0.034028 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046859 | 0.046859 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.033282 | 0.033282 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048248 | 0.048248 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000014 | 0.034704 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.033282 | 0.033282 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046498 | 0.046498 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000013 | 0.033846 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.029214 | 0.029214 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.045990 | 0.045990 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000010 | 0.031005 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027612 | 0.027612 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044626 | 0.044626 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.024857 | 0.024857 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.028082 | 0.028082 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.041220 | 0.041220 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.023082 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.024857 | 0.024857 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027612 | 0.027612 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.022778 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.025429 | 0.025429 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027142 | 0.027142 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.038337 | 0.038337 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.022163 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.023031 | 0.023031 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.022751 | 0.022751 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000004 | 0.020063 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.017939 | 0.017939 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.020355 | 0.020355 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.028844 | 0.028844 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.013690 | 0.013690 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.017043 | 0.017043 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.015832 | 0.015832 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.025304 | 0.025304 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.009200 | 0.009200 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011929 | 0.011929 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011929 | 0.011929 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.019930 | 0.019930 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.008924 | 0.008924 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.008474 | 0.008474 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.013763 | 0.013763 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.004079 | 0.004079 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006623 | 0.006623 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002272 | 0.002272 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002350 | 0.002350 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.045210 | 0.045210 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.043545 | 0.043545 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.041184 | 0.041184 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.040685 | 0.040685 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.035982 | 0.035982 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.031633 | 0.031633 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.020774 | 0.020774 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.007148 | 0.007148 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000709 | 0.000709 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096934 | 0.096934 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096934 | 0.096934 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092813 | 0.092813 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092813 | 0.092813 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.093749 | 0.093749 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092706 | 0.092706 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092706 | 0.092706 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100503 | 0.100503 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.097595 | 0.097595 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.293189 | 0.106299 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.103154 | 0.103154 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.087504 | 0.087504 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.293189 | 0.106299 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.103154 | 0.103154 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.094323 | 0.094323 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.294705 | 0.110550 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.102764 | 0.102764 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.079055 | 0.079055 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.285780 | 0.105624 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.111152 | 0.111152 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.078824 | 0.078824 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.102892 | 0.102892 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.081631 | 0.081631 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.105471 | 0.105471 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086118 | 0.086118 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.105471 | 0.105471 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.095298 | 0.095298 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.083869 | 0.083869 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096918 | 0.096918 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086484 | 0.086484 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.252373 | 0.098253 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096918 | 0.096918 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.085819 | 0.085819 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.245976 | 0.095698 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.116646 | 0.116646 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.088159 | 0.088159 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.248120 | 0.101661 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108392 | 0.108392 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.085410 | 0.085410 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.113752 | 0.113752 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.110319 | 0.110319 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086283 | 0.086283 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.253671 | 0.117220 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.113752 | 0.113752 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108392 | 0.108392 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.253883 | 0.117818 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.112639 | 0.112639 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.106464 | 0.106464 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.084655 | 0.084655 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.254313 | 0.119031 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108759 | 0.108759 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.109304 | 0.109304 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.237028 | 0.111720 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.113108 | 0.113108 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.111142 | 0.111142 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100269 | 0.100269 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.122241 | 0.122241 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.114954 | 0.114954 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.117506 | 0.117506 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086168 | 0.086168 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.124339 | 0.124339 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123397 | 0.123397 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123397 | 0.123397 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100539 | 0.100539 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.125108 | 0.125108 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123280 | 0.123280 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.116137 | 0.116137 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.128994 | 0.128994 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.122630 | 0.122630 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.124977 | 0.124977 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.138383 | 0.138383 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.075464 | 0.075464 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.081411 | 0.081411 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.075076 | 0.075076 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.077380 | 0.077380 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.091430 | 0.091430 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.096904 | 0.096904 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.101180 | 0.101180 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.111543 | 0.111543 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.137764 | 0.137764 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] $PA = (BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084140 | 0.084140 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084140 | 0.084140 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079884 | 0.079884 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079884 | 0.079884 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.080492 | 0.080492 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079490 | 0.079490 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079490 | 0.079490 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085092 | 0.085092 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082175 | 0.082175 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.054561 | 0.087617 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085406 | 0.085406 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077104 | 0.077104 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.054561 | 0.087617 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085406 | 0.085406 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081802 | 0.081802 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.053453 | 0.089890 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085187 | 0.085187 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069887 | 0.069887 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.052013 | 0.086279 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.089661 | 0.089661 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069720 | 0.069720 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082758 | 0.082758 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072423 | 0.072423 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084021 | 0.084021 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075631 | 0.075631 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084021 | 0.084021 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075604 | 0.075604 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072444 | 0.072444 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076364 | 0.076364 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074784 | 0.074784 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.042584 | 0.077904 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076364 | 0.076364 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.073729 | 0.073729 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.041288 | 0.075794 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.087244 | 0.087244 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075238 | 0.075238 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.039718 | 0.078448 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081036 | 0.081036 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072807 | 0.072807 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082780 | 0.082780 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082540 | 0.082540 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072232 | 0.072232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035639 | 0.083755 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082780 | 0.082780 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081036 | 0.081036 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035483 | 0.083911 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082441 | 0.082441 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079531 | 0.079531 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.070024 | 0.070024 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035166 | 0.084216 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078482 | 0.078482 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078636 | 0.078636 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.031893 | 0.078233 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.077409 | 0.077409 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078098 | 0.078098 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076437 | 0.076437 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.078688 | 0.078688 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077743 | 0.077743 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078142 | 0.078142 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065371 | 0.065371 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.074144 | 0.074144 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077314 | 0.077314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077314 | 0.077314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.071308 | 0.071308 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.074122 | 0.074122 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072472 | 0.072472 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075334 | 0.075334 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.065858 | 0.065858 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068904 | 0.068904 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057501 | 0.057501 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.063314 | 0.063314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.065831 | 0.065831 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.069576 | 0.069576 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.064239 | 0.064239 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.065719 | 0.065719 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.073799 | 0.073799 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.075591 | 0.075591 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.072279 | 0.072279 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.064298 | 0.064298 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.050670 | 0.050670 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] $PA = (BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062009 | 0.062009 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062009 | 0.062009 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057783 | 0.057783 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057783 | 0.057783 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057925 | 0.057925 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057033 | 0.057033 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057033 | 0.057033 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059479 | 0.059479 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056742 | 0.056742 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001520 | 0.057871 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056930 | 0.056930 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058620 | 0.058620 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001520 | 0.057871 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056930 | 0.056930 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060154 | 0.060154 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001408 | 0.057703 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056929 | 0.056929 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053443 | 0.053443 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001384 | 0.055894 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056588 | 0.056588 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053375 | 0.053375 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051853 | 0.051853 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055835 | 0.055835 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051593 | 0.051593 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057080 | 0.057080 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051593 | 0.051593 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045939 | 0.045939 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.052735 | 0.052735 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045739 | 0.045739 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.054590 | 0.054590 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000971 | 0.047305 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045739 | 0.045739 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053068 | 0.053068 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000932 | 0.045893 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.046908 | 0.046908 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053404 | 0.053404 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000810 | 0.044976 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043476 | 0.043476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051525 | 0.051525 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.041967 | 0.041967 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.044369 | 0.044369 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.049174 | 0.049174 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000549 | 0.040860 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.041967 | 0.041967 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043476 | 0.043476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000540 | 0.040660 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042301 | 0.042301 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042582 | 0.042582 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.046440 | 0.046440 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000523 | 0.040245 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.039047 | 0.039047 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038876 | 0.038876 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000449 | 0.036530 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.034430 | 0.034430 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.036732 | 0.036732 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042687 | 0.042687 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.030775 | 0.030775 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.033728 | 0.033728 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.032723 | 0.032723 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.036007 | 0.036007 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.024656 | 0.024656 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028555 | 0.028555 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028555 | 0.028555 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.034135 | 0.034135 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.024316 | 0.024316 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.023377 | 0.023377 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.029913 | 0.029913 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.015764 | 0.015764 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.020188 | 0.020188 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.011026 | 0.011026 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.012031 | 0.012031 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.048882 | 0.048882 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.049476 | 0.049476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.045738 | 0.045738 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.046068 | 0.046068 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.046500 | 0.046500 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.044314 | 0.044314 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.035138 | 0.035138 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.019839 | 0.019839 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.006060 | 0.006060 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062377 | 0.062377 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064824 | 0.064824 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061974 | 0.061974 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061956 | 0.061956 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064396 | 0.064396 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005333 | 0.064870 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062964 | 0.062964 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056126 | 0.056126 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005213 | 0.062504 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063975 | 0.063975 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056031 | 0.056031 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058501 | 0.058501 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058605 | 0.058605 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.060404 | 0.060404 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052072 | 0.052072 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056283 | 0.056283 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058312 | 0.058312 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003846 | 0.053737 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056884 | 0.056884 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003700 | 0.052089 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.055998 | 0.055998 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057551 | 0.057551 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003341 | 0.052129 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.055476 | 0.055476 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052781 | 0.052781 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.053560 | 0.053560 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002517 | 0.050382 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002488 | 0.050266 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051160 | 0.051160 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050598 | 0.050598 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050901 | 0.050901 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002431 | 0.050018 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047584 | 0.047584 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047491 | 0.047491 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002121 | 0.045543 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.043662 | 0.043662 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.045667 | 0.045667 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.049839 | 0.049839 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.040997 | 0.040997 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.043182 | 0.043182 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.042467 | 0.042467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.041733 | 0.041733 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.034767 | 0.034767 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.041865 | 0.041865 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.034467 | 0.034467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033286 | 0.033286 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.039483 | 0.039483 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.025001 | 0.025001 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.029700 | 0.029700 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.018840 | 0.018840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.020840 | 0.020840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051602 | 0.051602 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.053055 | 0.053055 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.048796 | 0.048796 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.049443 | 0.049443 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051992 | 0.051992 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.050842 | 0.050842 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.042904 | 0.042904 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.028412 | 0.028412 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.012379 | 0.012379 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062377 | 0.062377 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064824 | 0.064824 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061974 | 0.061974 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061956 | 0.061956 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064396 | 0.064396 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005333 | 0.064870 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062964 | 0.062964 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056126 | 0.056126 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005213 | 0.062504 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063975 | 0.063975 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056031 | 0.056031 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058501 | 0.058501 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058605 | 0.058605 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.060404 | 0.060404 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052072 | 0.052072 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056283 | 0.056283 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058312 | 0.058312 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003846 | 0.053737 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056884 | 0.056884 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003700 | 0.052089 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.055998 | 0.055998 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057551 | 0.057551 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003341 | 0.052129 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.055476 | 0.055476 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052781 | 0.052781 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.053560 | 0.053560 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002517 | 0.050382 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002488 | 0.050266 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051160 | 0.051160 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050598 | 0.050598 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050901 | 0.050901 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)



# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002431 | 0.050018 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047584 | 0.047584 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047491 | 0.047491 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002121 | 0.045543 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.043662 | 0.043662 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.045667 | 0.045667 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.049839 | 0.049839 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.040997 | 0.040997 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.043182 | 0.043182 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.042467 | 0.042467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.041733 | 0.041733 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.034767 | 0.034767 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.041865 | 0.041865 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.034467 | 0.034467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033286 | 0.033286 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.039483 | 0.039483 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.025001 | 0.025001 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.029700 | 0.029700 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.018840 | 0.018840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.020840 | 0.020840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051602 | 0.051602 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.053055 | 0.053055 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.048796 | 0.048796 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.049443 | 0.049443 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051992 | 0.051992 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.050842 | 0.050842 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.042904 | 0.042904 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.028412 | 0.028412 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.012379 | 0.012379 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 2.8765 | 0.00 | 371.46 | 0.00 | 156.93 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.007454 | 0.007454 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 2.8765 | 0.00 | 413.38 | 0.00 | 155.05 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.007454 | 0.007454 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 2.8440 | 0.00 | 364.56 | 0.00 | 145.63 | 0 | 3 | 1.28 | 0.000013 | 0.000013 | 0.006193 | 0.006193 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 2.8440 | 2.8440 | 641.99 | 373.01 | 143.65 | 143.65 | 1 | 1 | 1.28 | 0.000013 | 0.000013 | 0.006193 | 0.006193 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 2.8328 | 2.8328 | 651.71 | 326.17 | 141.08 | 141.08 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.005895 | 0.005895 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 2.8290 | 0.00 | 341.97 | 0.00 | 138.86 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005722 | 0.005722 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 2.8290 | 0.00 | 337.31 | 0.00 | 136.80 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005722 | 0.005722 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 2.8912 | 0.00 | 335.42 | 0.00 | 135.51 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.004450 | 0.004450 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 2.8592 | 0.00 | 319.23 | 0.00 | 131.83 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.003938 | 0.003938 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.5700 | 2.6778 | 403.86 | 206.64 | 105.99 | 110.43 | 0 | 2 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002530 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 2.7463 | 0.00 | 197.98 | 0.00 | 113.26 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.002774 | 0.002774 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 3.1849 | 3.1849 | 756.40 | 756.40 | 131.34 | 131.34 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.009908 | 0.009908 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.5700 | 2.6778 | 403.26 | 241.54 | 103.75 | 108.11 | 0 | 1 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002530 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 2.7463 | 0.00 | 215.09 | 0.00 | 110.87 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002774 | 0.002774 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 3.0601 | 3.0601 | 594.06 | 594.06 | 123.54 | 123.54 | 2 | 0 | 1.28 | 0.000013 | 0.000013 | 0.007274 | 0.007274 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 2.5700 | 2.6129 | 380.93 | 192.30 | 101.47 | 103.17 | 0 | 2 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.001896 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 2.7543 | 2.7543 | 495.63 | 220.72 | 108.75 | 108.75 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.002845 | 0.002845 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 3.2242 | 3.2242 | 692.25 | 692.25 | 127.30 | 127.30 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.010348 | 0.010348 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 2.5700 | 2.6396 | 423.04 | 193.21 | 99.14 | 101.82 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002080 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 2.5809 | 2.5809 | 465.35 | 185.69 | 99.56 | 99.56 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.001594 | 0.001594 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 3.2286 | 3.2286 | 721.22 | 721.22 | 124.55 | 124.55 | 5 | 0 | 1.28 | 0.000013 | 0.000013 | 0.010453 | 0.010453 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 2.5809 | 2.5809 | 396.66 | 151.80 | 97.16 | 97.16 | 0 | 2 | 1.28 | 0.000013 | 0.000013 | 0.001485 | 0.001485 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 3.2489 | 3.2489 | 806.77 | 806.77 | 122.31 | 122.31 | 10 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011186 | 0.011186 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 2.5700 | 2.5700 | 363.12 | 174.07 | 94.30 | 94.30 | 0 | 5 | 1.28 | 0.000013 | 0.000013 | 0.001208 | 0.001208 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 3.1655 | 3.1655 | 768.73 | 768.73 | 116.15 | 116.15 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.009230 | 0.009230 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 2.5700 | 2.5700 | 355.42 | 164.74 | 91.79 | 91.79 | 1 | 3 | 1.28 | 0.000013 | 0.000013 | 0.001208 | 0.001208 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 2.5700 | 2.5700 | 303.12 | 132.88 | 89.20 | 89.20 | 7 | 40 | 1.28 | 0.000013 | 0.000013 | 0.001102 | 0.001102 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 3.0543 | 3.0543 | 499.38 | 499.38 | 106.01 | 106.01 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006557 | 0.006557 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 2.5700 | 2.5700 | 284.34 | 120.71 | 86.54 | 86.54 | 8 | 33 | 1.28 | 0.000013 | 0.000013 | 0.000950 | 0.000950 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 3.0543 | 3.0543 | 530.80 | 530.80 | 102.84 | 102.84 | 9 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006735 | 0.006735 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 2.5700 | 2.5700 | 259.18 | 137.21 | 83.79 | 83.79 | 0 | 2 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.001088 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 2.5700 | 2.5700 | 275.95 | 121.99 | 83.79 | 83.79 | 2 | 12 | 1.28 | 0.000013 | 0.000013 | 0.000950 | 0.000950 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 3.0141 | 3.0141 | 493.74 | 493.74 | 98.27 | 98.27 | 11 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005889 | 0.005889 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 2.5700 | 2.5700 | 238.59 | 113.98 | 80.95 | 80.95 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.001063 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 2.5700 | 2.5700 | 277.36 | 99.62 | 80.95 | 80.95 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.000302 | 0.000302 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 2.9656 | 2.9656 | 425.49 | 425.49 | 93.41 | 93.41 | 30 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005151 | 0.005151 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 2.5700 | 2.5700 | 219.06 | 109.78 | 78.00 | 78.00 | 0 | 1 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000603 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 2.5700 | 2.5700 | 233.28 | 101.84 | 78.00 | 78.00 | 14 | 35 | 1.28 | 0.000013 | 0.000013 | 0.000300 | 0.000300 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 2.9656 | 2.9656 | 425.52 | 425.52 | 90.01 | 90.01 | 8 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005010 | 0.005010 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 2.5700 | 2.5700 | 215.33 | 95.64 | 74.94 | 74.94 | 13 | 43 | 1.28 | 0.000013 | 0.000013 | 0.000164 | 0.000164 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 2.5700 | 2.5700 | 190.78 | 190.78 | 74.94 | 74.94 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000305 | 0.000305 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 2.8521 | 2.8521 | 371.44 | 371.44 | 83.17 | 83.17 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.003446 | 0.003446 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5700 | 2.5700 | 199.98 | 109.12 | 71.75 | 71.75 | 0 | 2 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000109 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 2.5700 | 2.5700 | 197.82 | 93.69 | 71.75 | 71.75 | 2 | 9 | 1.28 | 0.000013 | 0.000013 | 0.000164 | 0.000164 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 2.5700 | 2.5700 | 124.94 | 124.94 | 71.75 | 71.75 | 2 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000300 | 0.000300 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 2.5700 | 178.03 | 107.22 | 68.41 | 68.41 | 4 | 7 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000101 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 2.5700 | 2.5700 | 173.99 | 99.31 | 68.41 | 68.41 | 1 | 4 | 1.28 | 0.000013 | 0.000013 | 0.000187 | 0.000187 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 2.5700 | 2.5700 | 176.67 | 176.67 | 68.41 | 68.41 | 6 | 6 | 1.28 | 0.000013 | 0.000013 | 0.000295 | 0.000295 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 2.7855 | 2.7855 | 269.24 | 269.24 | 74.15 | 74.15 | 2 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002682 | 0.002682 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 2.5700 | 167.03 | 112.18 | 64.90 | 64.90 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000087 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 2.5700 | 2.5700 | 158.71 | 81.21 | 64.90 | 64.90 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.000137 | 0.000137 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 2.5700 | 2.5700 | 137.09 | 137.09 | 64.90 | 64.90 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000128 | 0.000128 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 2.5700 | 139.86 | 82.46 | 61.19 | 61.19 | 1 | 5 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000070 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 2.5700 | 2.5700 | 139.15 | 76.43 | 61.19 | 61.19 | 5 | 20 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 2.5700 | 2.5700 | 125.25 | 125.25 | 61.19 | 61.19 | 2 | 6 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 2.5700 | 2.5700 | 130.36 | 73.82 | 57.24 | 57.24 | 1 | 2 | 1.64 | 0.000013 | 0.000013 | 0.000042 | 0.000042 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 2.5700 | 2.5700 | 131.63 | 72.89 | 57.24 | 57.24 | 6 | 13 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 2.5700 | 2.5700 | 80.62 | 80.62 | 57.24 | 57.24 | 5 | 11 | 1.28 | 0.000013 | 0.000013 | 0.000075 | 0.000075 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 2.5700 | 2.5700 | 119.98 | 119.98 | 57.24 | 57.24 | 7 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000462 | 0.000462 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 2.5700 | 2.5700 | 101.11 | 59.36 | 52.99 | 52.99 | 0 | 7 | 1.64 | 0.000013 | 0.000013 | 0.000010 | 0.000010 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 2.5700 | 2.5700 | 116.52 | 55.03 | 52.99 | 52.99 | 2 | 11 | 1.28 | 0.000013 | 0.000013 | 0.000032 | 0.000032 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 2.5700 | 2.5700 | 106.29 | 106.29 | 52.99 | 52.99 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000022 | 0.000022 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 2.5700 | 2.5700 | 112.59 | 60.54 | 52.99 | 52.99 | 3 | 5 | 1.28 | 0.000013 | 0.000013 | 0.000426 | 0.000426 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 2.5700 | 2.5700 | 79.65 | 47.64 | 48.38 | 48.38 | 0 | 1 | 1.64 | 0.000013 | 0.000013 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 2.5700 | 2.5700 | 79.75 | 59.05 | 48.38 | 48.38 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000006 | 0.000006 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 2.5700 | 2.5700 | 76.81 | 76.81 | 48.38 | 48.38 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000006 | 0.000006 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 2.5700 | 2.5700 | 90.47 | 54.51 | 48.38 | 48.38 | 1 | 2 | 1.28 | 0.000013 | 0.000013 | 0.000094 | 0.000094 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 2.5700 | 2.5700 | 72.40 | 42.44 | 43.27 | 43.27 | 9 | 4 | 1.64 | 0.000013 | 0.000013 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 2.5700 | 2.5700 | 65.16 | 43.17 | 43.27 | 43.27 | 11 | 2 | 1.28 | 0.000013 | 0.000013 | 0.000001 | 0.000001 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 2.5700 | 2.5700 | 79.75 | 79.75 | 43.27 | 43.27 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000012 | 0.000012 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 2.5700 | 2.5700 | 49.52 | 33.01 | 37.47 | 37.47 | 0 | 1 | 1.64 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 2.5700 | 2.5700 | 48.89 | 48.89 | 37.47 | 37.47 | 1 | 1 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 2.5700 | 2.5700 | 20.15 | 20.15 | 30.60 | 30.60 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 2.5700 | 2.5700 | 26.84 | 26.84 | 21.63 | 21.63 | 2 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 3.2827 | 3.2827 | 347.43 | 347.43 | 96.84 | 96.84 | 1 | 0 | 1.28 | 0.000002 | 0.000002 | 0.007896 | 0.007896 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 3.0989 | 3.0989 | 270.64 | 270.64 | 85.47 | 85.47 | 5 | 0 | 1.28 | 0.000002 | 0.000002 | 0.005259 | 0.005259 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 3.1338 | 3.1338 | 254.34 | 254.34 | 82.86 | 82.86 | 18 | 0 | 1.28 | 0.000002 | 0.000002 | 0.005365 | 0.005365 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 3.0659 | 3.0659 | 219.55 | 219.55 | 76.99 | 76.99 | 11 | 0 | 1.28 | 0.000002 | 0.000002 | 0.004619 | 0.004619 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 2.6414 | 2.6414 | 128.65 | 128.65 | 58.93 | 58.93 | 11 | 0 | 1.28 | 0.000002 | 0.000002 | 0.001598 | 0.001598 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 2.5700 | 2.5700 | 101.43 | 101.43 | 52.33 | 52.33 | 2 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000765 | 0.000765 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 2.5700 | 2.5700 | 54.82 | 54.82 | 38.47 | 38.47 | 3 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000111 | 0.000111 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 2.5700 | 2.5700 | 24.45 | 24.45 | 25.69 | 25.69 | 1 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000001 | 0.000001 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.5700 | 2.5700 | 12.69 | 12.69 | 18.51 | 18.51 | 1 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.3860 | 0.00 | 514.69 | 0.00 | 184.72 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.049977 | 0.049977 | 0.000000 | 0.007050 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.3860 | 0.00 | 572.78 | 0.00 | 182.51 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.049977 | 0.049977 | 0.000000 | 0.005789 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.3622 | 0.00 | 509.51 | 0.00 | 172.16 | 0 | 3 | 1.28 | 0.000044 | 0.000044 | 0.046166 | 0.046166 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 3.3622 | 3.3622 | 897.24 | 521.32 | 169.82 | 169.82 | 1 | 1 | 1.28 | 0.000044 | 0.000044 | 0.046166 | 0.046166 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 3.3567 | 3.3567 | 915.08 | 457.97 | 167.17 | 167.17 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.045869 | 0.045869 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.3549 | 0.00 | 480.92 | 0.00 | 164.67 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.045161 | 0.045161 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.3549 | 0.00 | 474.37 | 0.00 | 162.23 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.045161 | 0.045161 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 3.7935 | 0.00 | 577.44 | 0.00 | 177.80 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.044565 | 0.044565 | 0.000000 | 0.002999 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 3.7639 | 0.00 | 553.20 | 0.00 | 173.54 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.042274 | 0.042274 | 0.000000 | 0.000346 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.5700 | 3.4123 | 403.86 | 335.55 | 105.99 | 140.72 | 0 | 2 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.039720 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 3.7087 | 0.00 | 361.05 | 0.00 | 152.94 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.039908 | 0.039908 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 3.9348 | 3.9348 | 1154.54 | 1154.54 | 162.27 | 162.27 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.050313 | 0.050313 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.5700 | 3.4123 | 403.26 | 392.22 | 103.75 | 137.76 | 0 | 1 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.039720 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 3.7087 | 0.00 | 392.24 | 0.00 | 149.72 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.039908 | 0.039908 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 3.8748 | 3.8748 | 952.46 | 952.46 | 156.43 | 156.43 | 2 | 0 | 1.28 | 0.000044 | 0.000044 | 0.048737 | 0.048737 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 2.5700 | 3.3806 | 380.93 | 321.89 | 101.47 | 133.48 | 0 | 2 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.037704 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 3.7126 | 3.7126 | 900.51 | 401.02 | 146.59 | 146.59 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.040083 | 0.040083 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 3.9424 | 3.9424 | 1035.01 | 1035.01 | 155.66 | 155.66 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.047508 | 0.047508 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 2.5700 | 3.3936 | 423.04 | 319.36 | 99.14 | 130.91 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.037502 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 3.6277 | 3.6277 | 919.42 | 366.88 | 139.94 | 139.94 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.036099 | 0.036099 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 3.9446 | 3.9446 | 1076.53 | 1076.53 | 152.16 | 152.16 | 5 | 0 | 1.28 | 0.000044 | 0.000044 | 0.047541 | 0.047541 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 3.6277 | 3.6277 | 783.71 | 299.93 | 136.57 | 136.57 | 0 | 2 | 1.28 | 0.000044 | 0.000044 | 0.033629 | 0.033629 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 3.9656 | 3.9656 | 1201.97 | 1201.97 | 149.29 | 149.29 | 10 | 0 | 1.28 | 0.000044 | 0.000044 | 0.049568 | 0.049568 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 3.5991 | 3.5991 | 712.18 | 341.40 | 132.06 | 132.06 | 0 | 5 | 1.28 | 0.000044 | 0.000044 | 0.032317 | 0.032317 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 3.9254 | 3.9254 | 1182.16 | 1182.16 | 144.04 | 144.04 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.048837 | 0.048837 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 3.5991 | 3.5991 | 697.07 | 323.10 | 128.54 | 128.54 | 1 | 3 | 1.28 | 0.000044 | 0.000044 | 0.032317 | 0.032317 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 3.5991 | 3.5991 | 594.49 | 260.61 | 124.92 | 124.92 | 7 | 40 | 1.28 | 0.000044 | 0.000044 | 0.029471 | 0.029471 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 3.8593 | 3.8593 | 797.31 | 797.31 | 133.95 | 133.95 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.043780 | 0.043780 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 3.5792 | 3.5792 | 551.48 | 234.11 | 120.52 | 120.52 | 8 | 33 | 1.28 | 0.000044 | 0.000044 | 0.028624 | 0.028624 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 3.8593 | 3.8593 | 847.46 | 847.46 | 129.95 | 129.95 | 9 | 0 | 1.28 | 0.000044 | 0.000044 | 0.045019 | 0.045019 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 2.5700 | 3.5942 | 259.18 | 268.37 | 83.79 | 117.18 | 0 | 2 | 1.64 | 0.000024 | 0.000044 | 0.000003 | 0.029969 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 3.5792 | 3.5792 | 535.21 | 236.60 | 116.69 | 116.69 | 2 | 12 | 1.28 | 0.000044 | 0.000044 | 0.028624 | 0.028624 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 3.8396 | 3.8396 | 801.25 | 801.25 | 125.18 | 125.18 | 11 | 0 | 1.28 | 0.000044 | 0.000044 | 0.043203 | 0.043203 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 2.5700 | 3.5942 | 238.59 | 222.93 | 80.95 | 113.21 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.000002 | 0.029263 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 3.4277 | 3.4277 | 493.36 | 177.21 | 107.96 | 107.96 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.023684 | 0.023684 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 3.8159 | 3.8159 | 704.48 | 704.48 | 120.19 | 120.19 | 30 | 0 | 1.28 | 0.000044 | 0.000044 | 0.042440 | 0.042440 | 1.000000 | 1.000000 | 0.0100 | 0.000001 | 0.000000 | 0.000001 |
| 37 | Ship | Tanker | 65,000 | 2.5700 | 3.5200 | 219.06 | 205.95 | 78.00 | 106.84 | 0 | 1 | 1.64 | 0.000024 | 0.000044 | 0.000002 | 0.026103 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 3.4343 | 3.4343 | 416.56 | 181.86 | 104.24 | 104.24 | 14 | 35 | 1.28 | 0.000044 | 0.000044 | 0.022509 | 0.022509 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 3.8159 | 3.8159 | 704.52 | 704.52 | 115.82 | 115.82 | 8 | 0 | 1.28 | 0.000044 | 0.000044 | 0.041238 | 0.041238 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 3.3645 | 3.3645 | 369.05 | 163.91 | 98.11 | 98.11 | 13 | 43 | 1.28 | 0.000044 | 0.000044 | 0.019714 | 0.019714 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 3.4343 | 3.4343 | 340.68 | 340.68 | 100.15 | 100.15 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.022874 | 0.022874 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 3.7604 | 3.7604 | 645.69 | 645.69 | 109.66 | 109.66 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.037547 | 0.037547 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5700 | 3.3186 | 199.98 | 181.95 | 71.75 | 92.65 | 0 | 2 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017968 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 3.1661 | 3.1661 | 300.23 | 142.20 | 88.39 | 88.39 | 2 | 9 | 1.28 | 0.000044 | 0.000044 | 0.019714 | 0.019714 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 3.4343 | 3.4343 | 223.10 | 223.10 | 95.88 | 95.88 | 2 | 0 | 1.28 | 0.000044 | 0.000044 | 0.022509 | 0.022509 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 3.3106 | 178.03 | 177.92 | 68.41 | 88.13 | 4 | 7 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017673 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 3.1770 | 3.1770 | 265.89 | 151.77 | 84.57 | 84.57 | 1 | 4 | 1.28 | 0.000044 | 0.000044 | 0.020286 | 0.020286 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 3.4343 | 3.4343 | 315.48 | 315.48 | 91.42 | 91.42 | 6 | 6 | 1.28 | 0.000044 | 0.000044 | 0.022144 | 0.022144 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 3.7278 | 3.7278 | 482.23 | 482.23 | 99.23 | 99.23 | 2 | 0 | 1.28 | 0.000044 | 0.000044 | 0.034653 | 0.034653 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 3.2943 | 167.03 | 184.32 | 64.90 | 83.19 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017081 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 3.1549 | 3.1549 | 239.16 | 122.38 | 79.67 | 79.67 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.018201 | 0.018201 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 3.3420 | 3.3420 | 231.81 | 231.81 | 84.40 | 84.40 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.017924 | 0.017924 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 3.2777 | 139.86 | 134.12 | 61.19 | 78.04 | 1 | 5 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.015406 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 3.1072 | 3.1072 | 203.41 | 111.72 | 73.98 | 73.98 | 5 | 20 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 3.2861 | 3.2861 | 204.77 | 204.77 | 78.24 | 78.24 | 2 | 6 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 3.2251 | 3.2251 | 205.29 | 116.26 | 71.83 | 71.83 | 1 | 2 | 1.64 | 0.000044 | 0.000044 | 0.013483 | 0.013483 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 3.1072 | 3.1072 | 192.41 | 106.55 | 69.20 | 69.20 | 6 | 13 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.2861 | 3.2861 | 131.81 | 131.81 | 73.19 | 73.19 | 5 | 11 | 1.28 | 0.000044 | 0.000044 | 0.015685 | 0.015685 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 3.4908 | 3.4908 | 221.36 | 221.36 | 77.75 | 77.75 | 7 | 0 | 1.28 | 0.000044 | 0.000044 | 0.024064 | 0.024064 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 3.0850 | 3.0850 | 145.70 | 85.54 | 63.61 | 63.61 | 0 | 7 | 1.64 | 0.000044 | 0.000044 | 0.009669 | 0.009669 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 3.0406 | 3.0406 | 163.10 | 77.03 | 62.70 | 62.70 | 2 | 11 | 1.28 | 0.000044 | 0.000044 | 0.012655 | 0.012655 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 3.1584 | 3.1584 | 160.53 | 160.53 | 65.12 | 65.12 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.011557 | 0.011557 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 3.4968 | 3.4968 | 208.44 | 112.08 | 72.10 | 72.10 | 3 | 5 | 1.28 | 0.000044 | 0.000044 | 0.021316 | 0.021316 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 2.9272 | 2.9272 | 103.33 | 61.81 | 55.10 | 55.10 | 0 | 1 | 1.64 | 0.000044 | 0.000044 | 0.006050 | 0.006050 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 2.9135 | 2.9135 | 102.50 | 75.90 | 54.84 | 54.84 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.008214 | 0.008214 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.0279 | 3.0279 | 106.61 | 106.61 | 56.99 | 56.99 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.008214 | 0.008214 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.3186 | 3.3186 | 150.85 | 90.89 | 62.47 | 62.47 | 1 | 2 | 1.28 | 0.000044 | 0.000044 | 0.015626 | 0.015626 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 2.9138 | 2.9138 | 93.07 | 54.56 | 49.06 | 49.06 | 9 | 4 | 1.64 | 0.000044 | 0.000044 | 0.005830 | 0.005830 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 2.8176 | 2.8176 | 78.32 | 51.89 | 47.44 | 47.44 | 11 | 2 | 1.28 | 0.000044 | 0.000044 | 0.005504 | 0.005504 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.1067 | 3.1067 | 116.54 | 116.54 | 52.30 | 52.30 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.009835 | 0.009835 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 2.6286 | 2.6286 | 51.80 | 34.53 | 38.33 | 38.33 | 0 | 1 | 1.64 | 0.000044 | 0.000044 | 0.002314 | 0.002314 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 2.8131 | 2.8131 | 58.58 | 58.58 | 41.02 | 41.02 | 1 | 1 | 1.28 | 0.000044 | 0.000044 | 0.004128 | 0.004128 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 2.5700 | 2.5700 | 20.15 | 20.15 | 30.60 | 30.60 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.001174 | 0.001174 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 2.5700 | 2.5700 | 26.84 | 26.84 | 21.63 | 21.63 | 2 | 0 | 1.28 | 0.000044 | 0.000044 | 0.001195 | 0.001195 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.2229 | 4.2229 | 574.94 | 574.94 | 124.58 | 124.58 | 1 | 0 | 1.28 | 0.000007 | 0.000007 | 0.042850 | 0.042850 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.1439 | 4.1439 | 483.95 | 483.95 | 114.30 | 114.30 | 5 | 0 | 1.28 | 0.000007 | 0.000007 | 0.040455 | 0.040455 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.1610 | 4.1610 | 448.40 | 448.40 | 110.02 | 110.02 | 18 | 0 | 1.28 | 0.000007 | 0.000007 | 0.038529 | 0.038529 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.1278 | 4.1278 | 397.98 | 397.98 | 103.65 | 103.65 | 11 | 0 | 1.28 | 0.000007 | 0.000007 | 0.037773 | 0.037773 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 3.9202 | 3.9202 | 283.35 | 283.35 | 87.46 | 87.46 | 11 | 0 | 1.28 | 0.000007 | 0.000007 | 0.031709 | 0.031709 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 3.7986 | 3.7986 | 221.58 | 221.58 | 77.34 | 77.34 | 2 | 0 | 1.28 | 0.000007 | 0.000007 | 0.026981 | 0.026981 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3.5251 | 3.5251 | 103.14 | 103.14 | 52.77 | 52.77 | 3 | 0 | 1.28 | 0.000007 | 0.000007 | 0.016380 | 0.016380 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 2.9492 | 2.9492 | 32.19 | 32.19 | 29.48 | 29.48 | 1 | 0 | 1.28 | 0.000007 | 0.000007 | 0.004607 | 0.004607 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.5700 | 2.5700 | 12.69 | 12.69 | 18.51 | 18.51 | 1 | 0 | 1.28 | 0.000007 | 0.000007 | 0.000293 | 0.000293 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000003** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.5148 | 0.00 | 554.61 | 0.00 | 191.75 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.065848 | 0.065848 | 0.000000 | 0.010865 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.5148 | 0.00 | 617.20 | 0.00 | 189.45 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065848 | 0.065848 | 0.000000 | 0.009650 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.4933 | 0.00 | 550.00 | 0.00 | 178.87 | 0 | 3 | 1.28 | 0.000024 | 0.000024 | 0.061753 | 0.061753 | 0.000000 | 0.003647 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 3.4933 | 3.4933 | 968.54 | 562.75 | 176.44 | 176.44 | 1 | 1 | 1.28 | 0.000024 | 0.000024 | 0.061753 | 0.061753 | 0.002164 | 0.002164 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 3.4892 | 3.4892 | 988.75 | 494.85 | 173.77 | 173.77 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.061766 | 0.061766 | 0.000491 | 0.000491 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.4879 | 0.00 | 519.81 | 0.00 | 171.20 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060928 | 0.060928 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.4879 | 0.00 | 512.72 | 0.00 | 168.66 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060928 | 0.060928 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.0217 | 0.00 | 649.00 | 0.00 | 188.49 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.062435 | 0.062435 | 0.000000 | 0.009133 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 3.9927 | 0.00 | 622.50 | 0.00 | 184.09 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059812 | 0.059812 | 0.000000 | 0.006693 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.5700 | 3.5981 | 403.86 | 373.08 | 105.99 | 148.38 | 0 | 2 | 10.20 | 0.000013 | 0.000024 | 0.000444 | 0.059645 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 3.9520 | 0.00 | 409.99 | 0.00 | 162.98 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.059101 | 0.059101 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 4.1244 | 4.1244 | 1268.53 | 1268.53 | 170.09 | 170.09 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.063449 | 0.063449 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.5700 | 3.5981 | 403.26 | 436.09 | 103.75 | 145.26 | 0 | 1 | 10.20 | 0.000013 | 0.000024 | 0.000444 | 0.059645 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 3.9520 | 0.00 | 445.41 | 0.00 | 159.55 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059101 | 0.059101 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 4.0808 | 4.0808 | 1056.44 | 1056.44 | 164.75 | 164.75 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064173 | 0.064173 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 2.5700 | 3.5747 | 380.93 | 359.93 | 101.47 | 141.14 | 0 | 2 | 10.20 | 0.000013 | 0.000024 | 0.000403 | 0.058743 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 3.9549 | 3.9549 | 1021.92 | 455.09 | 156.15 | 156.15 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.059164 | 0.059164 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 4.1240 | 4.1240 | 1132.58 | 1132.58 | 162.83 | 162.83 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058892 | 0.058892 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 2.5700 | 3.5843 | 423.04 | 356.27 | 99.14 | 138.27 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.000399 | 0.057505 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 3.8925 | 3.8925 | 1058.53 | 422.39 | 150.16 | 150.16 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.057374 | 0.057374 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 4.1256 | 4.1256 | 1177.63 | 1177.63 | 159.15 | 159.15 | 5 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058846 | 0.058846 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 3.8925 | 3.8925 | 902.28 | 345.31 | 146.54 | 146.54 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.053353 | 0.053353 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 4.1468 | 4.1468 | 1314.36 | 1314.36 | 156.11 | 156.11 | 10 | 0 | 1.28 | 0.000024 | 0.000024 | 0.061163 | 0.061163 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 3.8715 | 3.8715 | 824.03 | 395.02 | 142.06 | 142.06 | 0 | 5 | 1.28 | 0.000024 | 0.000024 | 0.052626 | 0.052626 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 4.1176 | 4.1176 | 1300.77 | 1300.77 | 151.09 | 151.09 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.061949 | 0.061949 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 3.8715 | 3.8715 | 806.55 | 373.85 | 138.27 | 138.27 | 1 | 3 | 1.28 | 0.000024 | 0.000024 | 0.052626 | 0.052626 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 3.8715 | 3.8715 | 687.85 | 301.53 | 134.37 | 134.37 | 7 | 40 | 1.28 | 0.000024 | 0.000024 | 0.047868 | 0.047868 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 4.0629 | 4.0629 | 883.65 | 883.65 | 141.01 | 141.01 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057474 | 0.057474 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 3.8568 | 3.8568 | 640.34 | 271.84 | 129.86 | 129.86 | 8 | 33 | 1.28 | 0.000024 | 0.000024 | 0.047365 | 0.047365 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 4.0629 | 4.0629 | 939.24 | 939.24 | 136.80 | 136.80 | 9 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059149 | 0.059149 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 2.5700 | 3.8678 | 259.18 | 310.79 | 83.79 | 126.10 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.000269 | 0.048933 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 3.8568 | 3.8568 | 621.46 | 274.73 | 125.74 | 125.74 | 2 | 12 | 1.28 | 0.000024 | 0.000024 | 0.047365 | 0.047365 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 4.0484 | 4.0484 | 890.76 | 890.76 | 131.99 | 131.99 | 11 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057553 | 0.057553 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 2.5700 | 3.8678 | 238.59 | 258.16 | 80.95 | 121.83 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000259 | 0.047747 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 3.7453 | 3.7453 | 589.03 | 211.58 | 117.97 | 117.97 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.045552 | 0.045552 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 4.0309 | 4.0309 | 786.12 | 786.12 | 126.96 | 126.96 | 30 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057567 | 0.057567 | 1.000000 | 1.000000 | 0.0200 | 0.000001 | 0.000000 | 0.000001 |
| 37 | Ship | Tanker | 65,000 | 2.5700 | 3.8132 | 219.06 | 241.69 | 78.00 | 115.74 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.000216 | 0.045704 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 3.7502 | 3.7502 | 496.71 | 216.85 | 113.82 | 113.82 | 14 | 35 | 1.28 | 0.000024 | 0.000024 | 0.042936 | 0.042936 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 4.0309 | 4.0309 | 786.17 | 786.17 | 122.34 | 122.34 | 8 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055888 | 0.055888 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 3.6988 | 3.6988 | 446.03 | 198.10 | 107.86 | 107.86 | 13 | 43 | 1.28 | 0.000024 | 0.000024 | 0.040452 | 0.040452 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 3.7502 | 3.7502 | 406.22 | 406.22 | 109.36 | 109.36 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043650 | 0.043650 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 3.9901 | 3.9901 | 726.99 | 726.99 | 116.35 | 116.35 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053096 | 0.053096 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5700 | 3.6650 | 199.98 | 221.93 | 71.75 | 102.32 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.000132 | 0.038742 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 3.4169 | 3.4169 | 349.69 | 165.62 | 95.40 | 95.40 | 2 | 9 | 1.28 | 0.000024 | 0.000024 | 0.040452 | 0.040452 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 3.7502 | 3.7502 | 266.03 | 266.03 | 104.70 | 104.70 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042936 | 0.042936 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 3.6591 | 178.03 | 217.35 | 68.41 | 97.41 | 4 | 7 | 1.64 | 0.000013 | 0.000024 | 0.000129 | 0.038441 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 3.4250 | 3.4250 | 309.01 | 176.38 | 91.17 | 91.17 | 1 | 4 | 1.28 | 0.000024 | 0.000024 | 0.040985 | 0.040985 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 3.7502 | 3.7502 | 376.19 | 376.19 | 99.83 | 99.83 | 6 | 6 | 1.28 | 0.000024 | 0.000024 | 0.042222 | 0.042222 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 3.9661 | 3.9661 | 545.86 | 545.86 | 105.58 | 105.58 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.050259 | 0.050259 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 3.6472 | 167.03 | 225.92 | 64.90 | 92.11 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000124 | 0.037823 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 3.4087 | 3.4087 | 279.19 | 142.86 | 86.08 | 86.08 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.037904 | 0.037904 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 3.6822 | 3.6822 | 281.42 | 281.42 | 92.99 | 92.99 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.037635 | 0.037635 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 3.6349 | 139.86 | 164.95 | 61.19 | 86.55 | 1 | 5 | 1.64 | 0.000013 | 0.000024 | 0.000106 | 0.034699 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 3.3736 | 3.3736 | 239.77 | 131.69 | 80.32 | 80.32 | 5 | 20 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 3.6411 | 3.6411 | 251.40 | 251.40 | 86.69 | 86.69 | 2 | 6 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 3.5962 | 3.5962 | 255.26 | 144.56 | 80.09 | 80.09 | 1 | 2 | 1.64 | 0.000024 | 0.000024 | 0.032215 | 0.032215 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 3.3736 | 3.3736 | 226.82 | 125.60 | 75.14 | 75.14 | 6 | 13 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.6411 | 3.6411 | 161.83 | 161.83 | 81.09 | 81.09 | 5 | 11 | 1.28 | 0.000024 | 0.000024 | 0.034999 | 0.034999 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 3.7918 | 3.7918 | 261.17 | 261.17 | 84.45 | 84.45 | 7 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043318 | 0.043318 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 3.4931 | 3.4931 | 186.80 | 109.67 | 72.03 | 72.03 | 0 | 7 | 1.64 | 0.000024 | 0.000024 | 0.027260 | 0.027260 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 3.3246 | 3.3246 | 194.99 | 92.09 | 68.55 | 68.55 | 2 | 11 | 1.28 | 0.000024 | 0.000024 | 0.031223 | 0.031223 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 3.5471 | 3.5471 | 202.48 | 202.48 | 73.14 | 73.14 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.029841 | 0.029841 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 3.7961 | 3.7961 | 245.66 | 132.10 | 78.28 | 78.28 | 3 | 5 | 1.28 | 0.000024 | 0.000024 | 0.037981 | 0.037981 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.3771 | 3.3771 | 137.53 | 82.27 | 63.57 | 63.57 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.020767 | 0.020767 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 3.2311 | 3.2311 | 126.06 | 93.34 | 60.82 | 60.82 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.024832 | 0.024832 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.4511 | 3.4511 | 138.50 | 138.50 | 64.96 | 64.96 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.024832 | 0.024832 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.6650 | 3.6650 | 183.99 | 110.86 | 68.99 | 68.99 | 1 | 2 | 1.28 | 0.000024 | 0.000024 | 0.033574 | 0.033574 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.3671 | 3.3671 | 124.28 | 72.86 | 56.69 | 56.69 | 9 | 4 | 1.64 | 0.000024 | 0.000024 | 0.020363 | 0.020363 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.1605 | 3.1605 | 98.54 | 65.29 | 53.21 | 53.21 | 11 | 2 | 1.28 | 0.000024 | 0.000024 | 0.019567 | 0.019567 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.5091 | 3.5091 | 148.69 | 148.69 | 59.08 | 59.08 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.026989 | 0.026989 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.1573 | 3.1573 | 74.73 | 49.82 | 46.03 | 46.03 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.011894 | 0.011894 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.2931 | 3.2931 | 80.27 | 80.27 | 48.01 | 48.01 | 1 | 1 | 1.28 | 0.000024 | 0.000024 | 0.016457 | 0.016457 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.0239 | 3.0239 | 27.89 | 27.89 | 36.00 | 36.00 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.007843 | 0.007843 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.0076 | 3.0076 | 36.76 | 36.76 | 25.32 | 25.32 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.008244 | 0.008244 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.4607 | 4.4607 | 641.51 | 641.51 | 131.60 | 131.60 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.054402 | 0.054402 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.4082 | 4.4082 | 547.65 | 547.65 | 121.59 | 121.59 | 5 | 0 | 1.28 | 0.000004 | 0.000004 | 0.054213 | 0.054213 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.4208 | 4.4208 | 506.14 | 506.14 | 116.89 | 116.89 | 18 | 0 | 1.28 | 0.000004 | 0.000004 | 0.051002 | 0.051002 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.3964 | 4.3964 | 451.45 | 451.45 | 110.39 | 110.39 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.051022 | 0.051022 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.2436 | 4.2436 | 332.03 | 332.03 | 94.67 | 94.67 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.049171 | 0.049171 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.1541 | 4.1541 | 265.00 | 265.00 | 84.58 | 84.58 | 2 | 0 | 1.28 | 0.000004 | 0.000004 | 0.045734 | 0.045734 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3.9529 | 3.9529 | 129.69 | 129.69 | 59.17 | 59.17 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.034611 | 0.034611 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.5291 | 3.5291 | 46.10 | 46.10 | 35.28 | 35.28 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.016931 | 0.016931 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.7802 | 2.7802 | 14.85 | 14.85 | 20.02 | 20.02 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.003564 | 0.003564 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000004** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.6365 | 0.00 | 593.66 | 0.00 | 198.39 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.076995 | 0.076995 | 0.000000 | 0.014218 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.6365 | 0.00 | 660.65 | 0.00 | 196.01 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076995 | 0.076995 | 0.000000 | 0.013043 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.6170 | 0.00 | 589.64 | 0.00 | 185.20 | 0 | 3 | 1.28 | 0.000024 | 0.000024 | 0.072779 | 0.072779 | 0.000000 | 0.007322 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 3.6170 | 3.6170 | 1038.35 | 603.31 | 182.68 | 182.68 | 1 | 1 | 1.28 | 0.000024 | 0.000024 | 0.072779 | 0.072779 | 0.005890 | 0.005890 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 3.6143 | 3.6143 | 1060.90 | 530.95 | 180.00 | 180.00 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.073140 | 0.073140 | 0.004318 | 0.004318 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.6134 | 0.00 | 557.90 | 0.00 | 177.36 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072200 | 0.072200 | 0.000000 | 0.002732 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.6134 | 0.00 | 550.29 | 0.00 | 174.73 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072200 | 0.072200 | 0.000000 | 0.001102 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2371 | 0.00 | 720.37 | 0.00 | 198.59 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.076095 | 0.076095 | 0.000000 | 0.014317 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.2086 | 0.00 | 691.66 | 0.00 | 194.05 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.073275 | 0.073275 | 0.000000 | 0.012051 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.6796 | 3.7734 | 439.04 | 410.32 | 110.51 | 155.61 | 0 | 2 | 10.20 | 0.000013 | 0.000024 | 0.009723 | 0.076286 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1818 | 0.00 | 459.04 | 0.00 | 172.45 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.074796 | 0.074796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 4.3034 | 4.3034 | 1381.03 | 1381.03 | 177.47 | 177.47 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.071830 | 0.071830 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.6796 | 3.7734 | 438.39 | 479.62 | 108.18 | 152.34 | 0 | 1 | 10.20 | 0.000013 | 0.000024 | 0.009723 | 0.076286 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1818 | 0.00 | 498.70 | 0.00 | 168.82 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074796 | 0.074796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 4.2752 | 4.2752 | 1159.53 | 1159.53 | 172.60 | 172.60 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074919 | 0.074919 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 2.6695 | 3.7580 | 411.01 | 397.78 | 105.40 | 148.38 | 0 | 2 | 10.20 | 0.000013 | 0.000024 | 0.009269 | 0.077133 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 4.1837 | 4.1837 | 1143.55 | 509.26 | 165.19 | 165.19 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.074701 | 0.074701 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 4.2955 | 4.2955 | 1228.70 | 1228.70 | 169.60 | 169.60 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065658 | 0.065658 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 2.6737 | 3.7643 | 457.86 | 392.95 | 103.14 | 145.21 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.009073 | 0.074555 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 4.1424 | 4.1424 | 1198.80 | 478.36 | 159.80 | 159.80 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.076360 | 0.076360 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 4.2965 | 4.2965 | 1277.21 | 1277.21 | 165.74 | 165.74 | 5 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065539 | 0.065539 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 4.1424 | 4.1424 | 1021.84 | 391.07 | 155.95 | 155.95 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.070669 | 0.070669 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 4.3179 | 4.3179 | 1425.05 | 1425.05 | 162.55 | 162.55 | 10 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068095 | 0.068095 | 1.000000 | 1.000000 | 0.0400 | 0.000001 | 0.000000 | 0.000001 |
| 24 | Ship | Bulk Carrier | 95,000 | 4.1285 | 4.1285 | 937.07 | 449.20 | 151.49 | 151.49 | 0 | 5 | 1.28 | 0.000024 | 0.000024 | 0.071012 | 0.071012 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 4.2991 | 4.2991 | 1417.90 | 1417.90 | 157.74 | 157.74 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.070341 | 0.070341 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 4.1285 | 4.1285 | 917.19 | 425.13 | 147.45 | 147.45 | 1 | 3 | 1.28 | 0.000024 | 0.000024 | 0.071012 | 0.071012 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 4.1285 | 4.1285 | 782.21 | 342.90 | 143.29 | 143.29 | 7 | 40 | 1.28 | 0.000024 | 0.000024 | 0.064146 | 0.064146 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 4.2550 | 4.2550 | 969.22 | 969.22 | 147.68 | 147.68 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.066612 | 0.066612 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 4.1188 | 4.1188 | 730.30 | 310.03 | 138.69 | 138.69 | 8 | 33 | 1.28 | 0.000024 | 0.000024 | 0.064317 | 0.064317 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 4.2550 | 4.2550 | 1030.18 | 1030.18 | 143.27 | 143.27 | 9 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068689 | 0.068689 | 1.000000 | 1.000000 | 0.0400 | 0.000001 | 0.000000 | 0.000001 |
| 31 | Ship | Tanker | 75,000 | 2.6561 | 4.1261 | 276.84 | 353.67 | 86.60 | 134.52 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.006930 | 0.065910 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 4.1188 | 4.1188 | 708.76 | 313.32 | 134.28 | 134.28 | 2 | 12 | 1.28 | 0.000024 | 0.000024 | 0.064317 | 0.064317 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 4.2455 | 4.2455 | 979.58 | 979.58 | 138.41 | 138.41 | 11 | 0 | 1.28 | 0.000024 | 0.000024 | 0.067403 | 0.067403 | 1.000000 | 1.000000 | 0.0400 | 0.000001 | 0.000000 | 0.000001 |
| 34 | Ship | Tanker | 70,000 | 2.6561 | 4.1261 | 254.84 | 293.79 | 83.66 | 129.96 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.006697 | 0.064192 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 4.0451 | 4.0451 | 687.10 | 246.80 | 127.41 | 127.41 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.069100 | 0.069100 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 4.2339 | 4.2339 | 867.29 | 867.29 | 133.36 | 133.36 | 30 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068294 | 0.068294 | 1.000000 | 1.000000 | 0.0400 | 0.000003 | 0.000000 | 0.000003 |
| 37 | Ship | Tanker | 65,000 | 2.6382 | 4.0900 | 230.85 | 278.04 | 80.07 | 124.14 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.006126 | 0.064613 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 4.0483 | 4.0483 | 578.82 | 252.70 | 122.87 | 122.87 | 14 | 35 | 1.28 | 0.000024 | 0.000024 | 0.064521 | 0.064521 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 4.2339 | 4.2339 | 867.34 | 867.34 | 128.51 | 128.51 | 8 | 0 | 1.28 | 0.000024 | 0.000024 | 0.066163 | 0.066163 | 1.000000 | 1.000000 | 0.0400 | 0.000001 | 0.000000 | 0.000001 |
| 40 | Ship | Bulk Carrier | 60,000 | 4.0143 | 4.0143 | 525.38 | 233.34 | 117.06 | 117.06 | 13 | 43 | 1.28 | 0.000024 | 0.000024 | 0.064034 | 0.064034 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 4.0483 | 4.0483 | 473.38 | 473.38 | 118.05 | 118.05 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065674 | 0.065674 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 4.2069 | 4.2069 | 808.15 | 808.15 | 122.68 | 122.68 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064635 | 0.064635 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5893 | 3.9920 | 203.00 | 263.29 | 72.29 | 111.45 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.004785 | 0.063531 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 3.6536 | 3.6536 | 399.82 | 189.36 | 102.01 | 102.01 | 2 | 9 | 1.28 | 0.000024 | 0.000024 | 0.064034 | 0.064034 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.0483 | 4.0483 | 310.00 | 310.00 | 113.02 | 113.02 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064521 | 0.064521 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5874 | 3.9881 | 180.44 | 258.19 | 68.88 | 106.16 | 4 | 7 | 1.64 | 0.000013 | 0.000024 | 0.004737 | 0.063430 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 3.6590 | 3.6590 | 352.68 | 201.30 | 97.40 | 97.40 | 1 | 4 | 1.28 | 0.000024 | 0.000024 | 0.064165 | 0.064165 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 4.0483 | 4.0483 | 438.37 | 438.37 | 107.76 | 107.76 | 6 | 6 | 1.28 | 0.000024 | 0.000024 | 0.063369 | 0.063369 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000001 |
| 49 | Ship | Container | 50,000 | 4.1911 | 4.1911 | 609.53 | 609.53 | 111.57 | 111.57 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062129 | 0.062129 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5834 | 3.9802 | 168.78 | 269.06 | 65.24 | 100.52 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.004642 | 0.063212 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 3.6482 | 3.6482 | 319.80 | 163.64 | 92.13 | 92.13 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.060458 | 0.060458 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 4.0034 | 4.0034 | 332.65 | 332.65 | 101.10 | 101.10 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060381 | 0.060381 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5793 | 3.9721 | 140.87 | 196.98 | 61.41 | 94.57 | 1 | 5 | 1.64 | 0.000013 | 0.000024 | 0.004117 | 0.058462 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 3.6250 | 3.6250 | 276.84 | 152.05 | 86.31 | 86.31 | 5 | 20 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 3.9762 | 3.9762 | 299.80 | 299.80 | 94.67 | 94.67 | 2 | 6 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000001 |
| 56 | Ship | Tanker | 35,000 | 3.9465 | 3.9465 | 307.41 | 174.09 | 87.90 | 87.90 | 1 | 2 | 1.64 | 0.000024 | 0.000024 | 0.056546 | 0.056546 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 3.6250 | 3.6250 | 261.88 | 145.01 | 80.74 | 80.74 | 6 | 13 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.9762 | 3.9762 | 192.98 | 192.98 | 88.56 | 88.56 | 5 | 11 | 1.28 | 0.000024 | 0.000024 | 0.058577 | 0.058577 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000001 | 0.000001 |
| 59 | Ship | Container | 35,000 | 4.0758 | 4.0758 | 301.76 | 301.76 | 90.78 | 90.78 | 7 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062339 | 0.062339 | 1.000000 | 1.000000 | 0.0400 | 0.000001 | 0.000000 | 0.000001 |
| 60 | Ship | Tanker | 30,000 | 3.8783 | 3.8783 | 230.27 | 135.19 | 79.97 | 79.97 | 0 | 7 | 1.64 | 0.000024 | 0.000024 | 0.053837 | 0.053837 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 3.5926 | 3.5926 | 227.69 | 107.54 | 74.08 | 74.08 | 2 | 11 | 1.28 | 0.000024 | 0.000024 | 0.056074 | 0.056074 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 3.9141 | 3.9141 | 246.54 | 246.54 | 80.71 | 80.71 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055356 | 0.055356 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 4.0787 | 4.0787 | 283.58 | 152.49 | 84.10 | 84.10 | 3 | 5 | 1.28 | 0.000024 | 0.000024 | 0.053796 | 0.053796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.8016 | 3.8016 | 174.28 | 104.25 | 71.56 | 71.56 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.047021 | 0.047021 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 3.5308 | 3.5308 | 150.53 | 111.46 | 66.46 | 66.46 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051487 | 0.051487 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.8506 | 3.8506 | 172.42 | 172.42 | 72.48 | 72.48 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051487 | 0.051487 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.9920 | 3.9920 | 218.28 | 131.52 | 75.14 | 75.14 | 1 | 2 | 1.28 | 0.000024 | 0.000024 | 0.054439 | 0.054439 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.7951 | 3.7951 | 157.88 | 92.55 | 63.89 | 63.89 | 9 | 4 | 1.64 | 0.000024 | 0.000024 | 0.046684 | 0.046684 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.4841 | 3.4841 | 119.75 | 79.34 | 58.66 | 58.66 | 11 | 2 | 1.28 | 0.000024 | 0.000024 | 0.045363 | 0.045363 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.8889 | 3.8889 | 182.62 | 182.62 | 65.47 | 65.47 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.052166 | 0.052166 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.6563 | 3.6563 | 100.23 | 66.82 | 53.31 | 53.31 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.035708 | 0.035708 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.7461 | 3.7461 | 103.88 | 103.88 | 54.62 | 54.62 | 1 | 1 | 1.28 | 0.000024 | 0.000024 | 0.041284 | 0.041284 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5681 | 3.5681 | 38.83 | 38.83 | 42.48 | 42.48 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028207 | 0.028207 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5573 | 3.5573 | 51.42 | 51.42 | 29.95 | 29.95 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.030537 | 0.030537 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6851 | 4.6851 | 707.69 | 707.69 | 138.22 | 138.22 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.061418 | 0.061418 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6577 | 4.6577 | 611.38 | 611.38 | 128.47 | 128.47 | 5 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063565 | 0.063565 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6660 | 4.6660 | 563.84 | 563.84 | 123.37 | 123.37 | 18 | 0 | 1.28 | 0.000004 | 0.000004 | 0.059083 | 0.059083 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6498 | 4.6498 | 505.01 | 505.01 | 116.76 | 116.76 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.059964 | 0.059964 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.5488 | 4.5488 | 381.52 | 381.52 | 101.48 | 101.48 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063764 | 0.063764 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4897 | 4.4897 | 309.54 | 309.54 | 91.41 | 91.41 | 2 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063104 | 0.063104 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.3566 | 4.3566 | 157.54 | 157.54 | 65.21 | 65.21 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.055513 | 0.055513 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 4.0765 | 4.0765 | 61.51 | 61.51 | 40.75 | 40.75 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.039897 | 0.039897 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.5813 | 3.5813 | 24.65 | 24.65 | 25.79 | 25.79 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.019611 | 0.019611 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000011** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 4.4584 | 0.00 | 892.35 | 0.00 | 243.23 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.067016 | 0.067016 | 0.000000 | 0.032081 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 4.4584 | 0.00 | 993.05 | 0.00 | 240.31 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.067016 | 0.067016 | 0.000000 | 0.031123 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 4.4212 | 0.00 | 881.00 | 0.00 | 226.38 | 0 | 3 | 1.28 | 0.000036 | 0.000036 | 0.062814 | 0.062814 | 0.000000 | 0.026201 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 4.4212 | 4.4212 | 1551.42 | 901.42 | 223.30 | 223.30 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062814 | 0.062814 | 0.025030 | 0.025030 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 4.4158 | 4.4158 | 1583.58 | 792.54 | 219.91 | 219.91 | 1 | 1 | 1.28 | 0.000036 | 0.000036 | 0.062984 | 0.062984 | 0.023702 | 0.023702 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 4.4139 | 0.00 | 832.49 | 0.00 | 216.66 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062090 | 0.062090 | 0.000000 | 0.022389 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 4.4139 | 0.00 | 821.14 | 0.00 | 213.45 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.062090 | 0.062090 | 0.000000 | 0.021054 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2057 | 0.00 | 709.74 | 0.00 | 197.12 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064700 | 0.064700 | 0.000000 | 0.013594 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.1757 | 0.00 | 680.88 | 0.00 | 192.53 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061960 | 0.061960 | 0.000000 | 0.011270 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.5700 | 3.7451 | 403.86 | 404.19 | 105.99 | 154.45 | 3 | 0 | 10.20 | 0.000020 | 0.000036 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1451 | 0.00 | 451.03 | 0.00 | 170.94 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 4.7075 | 4.7075 | 1652.52 | 1652.52 | 194.13 | 194.13 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063374 | 0.063374 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.5700 | 3.7451 | 403.26 | 472.45 | 103.75 | 151.19 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1451 | 0.00 | 490.00 | 0.00 | 167.34 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 4.6680 | 4.6680 | 1382.38 | 1382.38 | 188.45 | 188.45 | 2 | 0 | 1.28 | 0.000036 | 0.000036 | 0.065140 | 0.065140 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 16 | Ship | Tanker | 110,000 | 2.5700 | 3.7274 | 380.93 | 391.33 | 101.47 | 147.17 | 2 | 0 | 10.20 | 0.000020 | 0.000036 | 0.001868 | 0.063170 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 4.1473 | 4.1473 | 1123.77 | 500.45 | 163.75 | 163.75 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062266 | 0.062266 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 4.6984 | 4.6984 | 1470.01 | 1470.01 | 185.51 | 185.51 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058063 | 0.058063 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 2.5700 | 3.7347 | 423.04 | 386.79 | 99.14 | 144.07 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.001837 | 0.061299 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 4.1000 | 4.1000 | 1174.40 | 468.63 | 158.16 | 158.16 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062070 | 0.062070 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 4.6999 | 4.6999 | 1528.26 | 1528.26 | 181.30 | 181.30 | 5 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057986 | 0.057986 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000000 | 0.000002 |
| 22 | Ship | Bulk Carrier | 100,000 | 4.1000 | 4.1000 | 1001.05 | 383.11 | 154.35 | 154.35 | 2 | 1 | 1.28 | 0.000036 | 0.000036 | 0.057246 | 0.057246 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 4.7276 | 4.7276 | 1708.31 | 1708.31 | 177.98 | 177.98 | 10 | 0 | 1.28 | 0.000036 | 0.000036 | 0.060442 | 0.060442 | 1.000000 | 1.000000 | 0.1400 | 0.000004 | 0.000000 | 0.000004 |
| 24 | Ship | Bulk Carrier | 95,000 | 4.0840 | 4.0840 | 916.97 | 439.57 | 149.85 | 149.85 | 3 | 2 | 1.28 | 0.000036 | 0.000036 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 4.7014 | 4.7014 | 1695.70 | 1695.70 | 172.51 | 172.51 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061855 | 0.061855 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 4.0840 | 4.0840 | 897.52 | 416.02 | 145.86 | 145.86 | 2 | 2 | 1.28 | 0.000036 | 0.000036 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 4.0840 | 4.0840 | 765.44 | 335.55 | 141.75 | 141.75 | 30 | 16 | 1.28 | 0.000036 | 0.000036 | 0.051251 | 0.051251 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 4.6420 | 4.6420 | 1153.54 | 1153.54 | 161.12 | 161.12 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057638 | 0.057638 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 4.0727 | 4.0727 | 714.07 | 303.13 | 137.14 | 137.14 | 29 | 13 | 1.28 | 0.000036 | 0.000036 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 4.6420 | 4.6420 | 1226.10 | 1226.10 | 156.31 | 156.31 | 10 | 0 | 1.28 | 0.000036 | 0.000036 | 0.059514 | 0.059514 | 1.000000 | 1.000000 | 0.1400 | 0.000004 | 0.000000 | 0.000004 |
| 31 | Ship | Tanker | 75,000 | 2.5700 | 4.4586 | 259.18 | 412.97 | 83.79 | 145.36 | 1 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001311 | 0.052648 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 4.0727 | 4.0727 | 693.00 | 306.36 | 132.78 | 132.78 | 9 | 5 | 1.28 | 0.000036 | 0.000036 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 4.6286 | 4.6286 | 1164.38 | 1164.38 | 150.91 | 150.91 | 11 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058034 | 0.058034 | 1.000000 | 1.000000 | 0.1400 | 0.000004 | 0.000000 | 0.000004 |
| 34 | Ship | Tanker | 70,000 | 2.5700 | 4.4586 | 238.59 | 343.05 | 80.95 | 140.43 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001261 | 0.051208 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 3.9866 | 3.9866 | 667.38 | 239.71 | 125.57 | 125.57 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052334 | 0.052334 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 4.6124 | 4.6124 | 1029.27 | 1029.27 | 145.28 | 145.28 | 30 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058442 | 0.058442 | 1.000000 | 1.000000 | 0.1400 | 0.000011 | 0.000000 | 0.000011 |
| 37 | Ship | Tanker | 65,000 | 2.5700 | 4.4062 | 219.06 | 322.70 | 78.00 | 133.73 | 1 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001103 | 0.050324 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 3.9904 | 3.9904 | 562.38 | 245.52 | 121.11 | 121.11 | 34 | 15 | 1.28 | 0.000036 | 0.000036 | 0.048809 | 0.048809 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 4.6124 | 4.6124 | 1029.34 | 1029.34 | 139.99 | 139.99 | 8 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056539 | 0.056539 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000000 | 0.000003 |
| 40 | Ship | Bulk Carrier | 60,000 | 3.9502 | 3.9502 | 508.72 | 225.94 | 115.19 | 115.19 | 45 | 11 | 1.28 | 0.000036 | 0.000036 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 4.3451 | 4.3451 | 545.34 | 545.34 | 126.71 | 126.71 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.049727 | 0.049727 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 4.5743 | 4.5743 | 955.44 | 955.44 | 133.39 | 133.39 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.054292 | 0.054292 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5700 | 4.2616 | 199.98 | 300.05 | 71.75 | 118.98 | 2 | 0 | 1.64 | 0.000020 | 0.000036 | 0.000761 | 0.046097 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 4.2949 | 4.2949 | 552.47 | 261.67 | 119.91 | 119.91 | 7 | 4 | 1.28 | 0.000036 | 0.000036 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.3451 | 4.3451 | 357.13 | 357.13 | 121.31 | 121.31 | 2 | 0 | 1.28 | 0.000036 | 0.000036 | 0.048809 | 0.048809 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 4.2558 | 178.03 | 294.01 | 68.41 | 113.29 | 8 | 3 | 1.64 | 0.000020 | 0.000036 | 0.000750 | 0.045886 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 4.3054 | 4.3054 | 488.31 | 278.72 | 114.61 | 114.61 | 4 | 1 | 1.28 | 0.000036 | 0.000036 | 0.047599 | 0.047599 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 4.3451 | 4.3451 | 505.01 | 505.01 | 115.67 | 115.67 | 6 | 6 | 1.28 | 0.000036 | 0.000036 | 0.047892 | 0.047892 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000002 | 0.000004 |
| 49 | Ship | Container | 50,000 | 4.5518 | 4.5518 | 718.96 | 718.96 | 121.17 | 121.17 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051584 | 0.051584 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 4.2440 | 167.03 | 305.90 | 64.90 | 107.18 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.000728 | 0.045451 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 4.2841 | 4.2841 | 441.00 | 225.66 | 108.19 | 108.19 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.044239 | 0.044239 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 4.2786 | 4.2786 | 379.96 | 379.96 | 108.05 | 108.05 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.044059 | 0.044059 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 4.2318 | 139.86 | 223.57 | 61.19 | 100.76 | 5 | 1 | 1.64 | 0.000020 | 0.000036 | 0.000630 | 0.041601 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 4.2379 | 4.2379 | 378.37 | 207.82 | 100.90 | 100.90 | 19 | 6 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 4.2379 | 4.2379 | 340.57 | 340.57 | 100.90 | 100.90 | 7 | 2 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000001 | 0.000003 |
| 56 | Ship | Tanker | 35,000 | 4.1933 | 4.1933 | 347.05 | 196.54 | 93.39 | 93.39 | 2 | 1 | 1.64 | 0.000036 | 0.000036 | 0.039387 | 0.039387 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 4.2379 | 4.2379 | 357.92 | 198.20 | 94.39 | 94.39 | 13 | 5 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 4.2379 | 4.2379 | 219.22 | 219.22 | 94.39 | 94.39 | 11 | 5 | 1.28 | 0.000036 | 0.000036 | 0.041816 | 0.041816 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000001 | 0.000004 |
| 59 | Ship | Container | 35,000 | 4.3855 | 4.3855 | 349.36 | 349.36 | 97.67 | 97.67 | 7 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047991 | 0.047991 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000000 | 0.000002 |
| 60 | Ship | Tanker | 30,000 | 4.0894 | 4.0894 | 256.02 | 150.31 | 84.32 | 84.32 | 7 | 0 | 1.64 | 0.000036 | 0.000036 | 0.035441 | 0.035441 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 4.1728 | 4.1728 | 307.18 | 145.07 | 86.04 | 86.04 | 10 | 4 | 1.28 | 0.000036 | 0.000036 | 0.038633 | 0.038633 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 4.1440 | 4.1440 | 276.36 | 276.36 | 85.45 | 85.45 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.037551 | 0.037551 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 4.3897 | 4.3897 | 328.48 | 176.63 | 90.51 | 90.51 | 5 | 3 | 1.28 | 0.000036 | 0.000036 | 0.041149 | 0.041149 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.9703 | 3.9703 | 190.09 | 113.71 | 74.73 | 74.73 | 1 | 0 | 1.64 | 0.000036 | 0.000036 | 0.028823 | 0.028823 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 4.0466 | 4.0466 | 197.72 | 146.40 | 76.17 | 76.17 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033052 | 0.033052 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 4.0466 | 4.0466 | 190.42 | 190.42 | 76.17 | 76.17 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033052 | 0.033052 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 4.2616 | 4.2616 | 248.76 | 149.88 | 80.22 | 80.22 | 2 | 1 | 1.28 | 0.000036 | 0.000036 | 0.039156 | 0.039156 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.9600 | 3.9600 | 171.90 | 100.77 | 66.67 | 66.67 | 4 | 10 | 1.64 | 0.000036 | 0.000036 | 0.028446 | 0.028446 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.9496 | 3.9496 | 153.88 | 101.96 | 66.49 | 66.49 | 2 | 10 | 1.28 | 0.000036 | 0.000036 | 0.027436 | 0.027436 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 4.1056 | 4.1056 | 203.54 | 203.54 | 69.12 | 69.12 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.034567 | 0.034567 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.7383 | 3.7383 | 104.77 | 69.85 | 54.51 | 54.51 | 1 | 0 | 1.64 | 0.000036 | 0.000036 | 0.018944 | 0.018944 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.8827 | 3.8827 | 111.59 | 111.59 | 56.61 | 56.61 | 2 | 1 | 1.28 | 0.000036 | 0.000036 | 0.023934 | 0.023934 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5932 | 3.5932 | 39.38 | 39.38 | 42.78 | 42.78 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.013574 | 0.013574 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5752 | 3.5752 | 51.94 | 51.94 | 30.10 | 30.10 | 3 | 0 | 1.28 | 0.000036 | 0.000036 | 0.014640 | 0.014640 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6540 | 4.6540 | 698.32 | 698.32 | 137.30 | 137.30 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.053600 | 0.053600 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6217 | 4.6217 | 601.96 | 601.96 | 127.47 | 127.47 | 5 | 0 | 1.28 | 0.000006 | 0.000006 | 0.054428 | 0.054428 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6310 | 4.6310 | 555.41 | 555.41 | 122.45 | 122.45 | 19 | 0 | 1.28 | 0.000006 | 0.000006 | 0.050608 | 0.050608 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6128 | 4.6128 | 497.00 | 497.00 | 115.83 | 115.83 | 11 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051012 | 0.051012 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.4979 | 4.4979 | 373.03 | 373.03 | 100.35 | 100.35 | 10 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051765 | 0.051765 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4296 | 4.4296 | 301.31 | 301.31 | 90.19 | 90.19 | 3 | 0 | 1.28 | 0.000006 | 0.000006 | 0.049628 | 0.049628 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.2730 | 4.2730 | 151.55 | 151.55 | 63.96 | 63.96 | 3 | 0 | 1.28 | 0.000006 | 0.000006 | 0.040202 | 0.040202 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.9292 | 3.9292 | 57.14 | 57.14 | 39.27 | 39.27 | 1 | 0 | 1.28 | 0.000006 | 0.000006 | 0.023659 | 0.023659 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.2707 | 3.2707 | 20.56 | 20.56 | 23.56 | 23.56 | 1 | 0 | 1.28 | 0.000006 | 0.000006 | 0.007671 | 0.007671 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000049** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 4.4584 | 0.00 | 892.35 | 0.00 | 243.23 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.067016 | 0.067016 | 0.000000 | 0.032081 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 4.4584 | 0.00 | 993.05 | 0.00 | 240.31 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.067016 | 0.067016 | 0.000000 | 0.031123 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 4.4212 | 0.00 | 881.00 | 0.00 | 226.38 | 0 | 3 | 1.28 | 0.000028 | 0.000028 | 0.062814 | 0.062814 | 0.000000 | 0.026201 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 4.4212 | 4.4212 | 1551.42 | 901.42 | 223.30 | 223.30 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062814 | 0.062814 | 0.025030 | 0.025030 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 4.4158 | 4.4158 | 1583.58 | 792.54 | 219.91 | 219.91 | 1 | 1 | 1.28 | 0.000028 | 0.000028 | 0.062984 | 0.062984 | 0.023702 | 0.023702 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 4.4139 | 0.00 | 832.49 | 0.00 | 216.66 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062090 | 0.062090 | 0.000000 | 0.022389 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 4.4139 | 0.00 | 821.14 | 0.00 | 213.45 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.062090 | 0.062090 | 0.000000 | 0.021054 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2057 | 0.00 | 709.74 | 0.00 | 197.12 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064700 | 0.064700 | 0.000000 | 0.013594 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.1757 | 0.00 | 680.88 | 0.00 | 192.53 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061960 | 0.061960 | 0.000000 | 0.011270 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.5700 | 3.7451 | 403.86 | 404.19 | 105.99 | 154.45 | 3 | 0 | 10.20 | 0.000015 | 0.000028 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1451 | 0.00 | 451.03 | 0.00 | 170.94 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 4.7075 | 4.7075 | 1652.52 | 1652.52 | 194.13 | 194.13 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063374 | 0.063374 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.5700 | 3.7451 | 403.26 | 472.45 | 103.75 | 151.19 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1451 | 0.00 | 490.00 | 0.00 | 167.34 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 4.6680 | 4.6680 | 1382.38 | 1382.38 | 188.45 | 188.45 | 2 | 0 | 1.28 | 0.000028 | 0.000028 | 0.065140 | 0.065140 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 16 | Ship | Tanker | 110,000 | 2.5700 | 3.7274 | 380.93 | 391.33 | 101.47 | 147.17 | 2 | 0 | 10.20 | 0.000015 | 0.000028 | 0.001868 | 0.063170 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 4.1473 | 4.1473 | 1123.77 | 500.45 | 163.75 | 163.75 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062266 | 0.062266 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 4.6984 | 4.6984 | 1470.01 | 1470.01 | 185.51 | 185.51 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058063 | 0.058063 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 2.5700 | 3.7347 | 423.04 | 386.79 | 99.14 | 144.07 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.001837 | 0.061299 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 4.1000 | 4.1000 | 1174.40 | 468.63 | 158.16 | 158.16 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062070 | 0.062070 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 4.6999 | 4.6999 | 1528.26 | 1528.26 | 181.30 | 181.30 | 5 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057986 | 0.057986 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 22 | Ship | Bulk Carrier | 100,000 | 4.1000 | 4.1000 | 1001.05 | 383.11 | 154.35 | 154.35 | 2 | 1 | 1.28 | 0.000028 | 0.000028 | 0.057246 | 0.057246 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 4.7276 | 4.7276 | 1708.31 | 1708.31 | 177.98 | 177.98 | 10 | 0 | 1.28 | 0.000028 | 0.000028 | 0.060442 | 0.060442 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000000 | 0.000003 |
| 24 | Ship | Bulk Carrier | 95,000 | 4.0840 | 4.0840 | 916.97 | 439.57 | 149.85 | 149.85 | 3 | 2 | 1.28 | 0.000028 | 0.000028 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 4.7014 | 4.7014 | 1695.70 | 1695.70 | 172.51 | 172.51 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061855 | 0.061855 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 4.0840 | 4.0840 | 897.52 | 416.02 | 145.86 | 145.86 | 2 | 2 | 1.28 | 0.000028 | 0.000028 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 4.0840 | 4.0840 | 765.44 | 335.55 | 141.75 | 141.75 | 30 | 16 | 1.28 | 0.000028 | 0.000028 | 0.051251 | 0.051251 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 4.6420 | 4.6420 | 1153.54 | 1153.54 | 161.12 | 161.12 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057638 | 0.057638 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 4.0727 | 4.0727 | 714.07 | 303.13 | 137.14 | 137.14 | 29 | 13 | 1.28 | 0.000028 | 0.000028 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 4.6420 | 4.6420 | 1226.10 | 1226.10 | 156.31 | 156.31 | 10 | 0 | 1.28 | 0.000028 | 0.000028 | 0.059514 | 0.059514 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000000 | 0.000003 |
| 31 | Ship | Tanker | 75,000 | 2.5700 | 4.4586 | 259.18 | 412.97 | 83.79 | 145.36 | 1 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001311 | 0.052648 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 4.0727 | 4.0727 | 693.00 | 306.36 | 132.78 | 132.78 | 9 | 5 | 1.28 | 0.000028 | 0.000028 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 4.6286 | 4.6286 | 1164.38 | 1164.38 | 150.91 | 150.91 | 11 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058034 | 0.058034 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000000 | 0.000003 |
| 34 | Ship | Tanker | 70,000 | 2.5700 | 4.4586 | 238.59 | 343.05 | 80.95 | 140.43 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001261 | 0.051208 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 3.9866 | 3.9866 | 667.38 | 239.71 | 125.57 | 125.57 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052334 | 0.052334 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 4.6124 | 4.6124 | 1029.27 | 1029.27 | 145.28 | 145.28 | 30 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058442 | 0.058442 | 1.000000 | 1.000000 | 0.1400 | 0.000009 | 0.000000 | 0.000009 |
| 37 | Ship | Tanker | 65,000 | 2.5700 | 4.4062 | 219.06 | 322.70 | 78.00 | 133.73 | 1 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001103 | 0.050324 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 3.9904 | 3.9904 | 562.38 | 245.52 | 121.11 | 121.11 | 34 | 15 | 1.28 | 0.000028 | 0.000028 | 0.048809 | 0.048809 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 4.6124 | 4.6124 | 1029.34 | 1029.34 | 139.99 | 139.99 | 8 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056539 | 0.056539 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000000 | 0.000002 |
| 40 | Ship | Bulk Carrier | 60,000 | 3.9502 | 3.9502 | 508.72 | 225.94 | 115.19 | 115.19 | 45 | 11 | 1.28 | 0.000028 | 0.000028 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 4.3451 | 4.3451 | 545.34 | 545.34 | 126.71 | 126.71 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.049727 | 0.049727 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 4.5743 | 4.5743 | 955.44 | 955.44 | 133.39 | 133.39 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.054292 | 0.054292 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5700 | 4.2616 | 199.98 | 300.05 | 71.75 | 118.98 | 2 | 0 | 1.64 | 0.000015 | 0.000028 | 0.000761 | 0.046097 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 4.2949 | 4.2949 | 552.47 | 261.67 | 119.91 | 119.91 | 7 | 4 | 1.28 | 0.000028 | 0.000028 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.3451 | 4.3451 | 357.13 | 357.13 | 121.31 | 121.31 | 2 | 0 | 1.28 | 0.000028 | 0.000028 | 0.048809 | 0.048809 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 4.2558 | 178.03 | 294.01 | 68.41 | 113.29 | 8 | 3 | 1.64 | 0.000015 | 0.000028 | 0.000750 | 0.045886 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 4.3054 | 4.3054 | 488.31 | 278.72 | 114.61 | 114.61 | 4 | 1 | 1.28 | 0.000028 | 0.000028 | 0.047599 | 0.047599 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 4.3451 | 4.3451 | 505.01 | 505.01 | 115.67 | 115.67 | 6 | 6 | 1.28 | 0.000028 | 0.000028 | 0.047892 | 0.047892 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000001 | 0.000003 |
| 49 | Ship | Container | 50,000 | 4.5518 | 4.5518 | 718.96 | 718.96 | 121.17 | 121.17 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051584 | 0.051584 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 4.2440 | 167.03 | 305.90 | 64.90 | 107.18 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.000728 | 0.045451 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 4.2841 | 4.2841 | 441.00 | 225.66 | 108.19 | 108.19 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.044239 | 0.044239 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 4.2786 | 4.2786 | 379.96 | 379.96 | 108.05 | 108.05 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.044059 | 0.044059 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 4.2318 | 139.86 | 223.57 | 61.19 | 100.76 | 5 | 1 | 1.64 | 0.000015 | 0.000028 | 0.000630 | 0.041601 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 4.2379 | 4.2379 | 378.37 | 207.82 | 100.90 | 100.90 | 19 | 6 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 4.2379 | 4.2379 | 340.57 | 340.57 | 100.90 | 100.90 | 7 | 2 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000000 | 0.000002 |
| 56 | Ship | Tanker | 35,000 | 4.1933 | 4.1933 | 347.05 | 196.54 | 93.39 | 93.39 | 2 | 1 | 1.64 | 0.000028 | 0.000028 | 0.039387 | 0.039387 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 4.2379 | 4.2379 | 357.92 | 198.20 | 94.39 | 94.39 | 13 | 5 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 4.2379 | 4.2379 | 219.22 | 219.22 | 94.39 | 94.39 | 11 | 5 | 1.28 | 0.000028 | 0.000028 | 0.041816 | 0.041816 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000001 | 0.000003 |
| 59 | Ship | Container | 35,000 | 4.3855 | 4.3855 | 349.36 | 349.36 | 97.67 | 97.67 | 7 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047991 | 0.047991 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000000 | 0.000002 |
| 60 | Ship | Tanker | 30,000 | 4.0894 | 4.0894 | 256.02 | 150.31 | 84.32 | 84.32 | 7 | 0 | 1.64 | 0.000028 | 0.000028 | 0.035441 | 0.035441 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 4.1728 | 4.1728 | 307.18 | 145.07 | 86.04 | 86.04 | 10 | 4 | 1.28 | 0.000028 | 0.000028 | 0.038633 | 0.038633 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 4.1440 | 4.1440 | 276.36 | 276.36 | 85.45 | 85.45 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.037551 | 0.037551 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 4.3897 | 4.3897 | 328.48 | 176.63 | 90.51 | 90.51 | 5 | 3 | 1.28 | 0.000028 | 0.000028 | 0.041149 | 0.041149 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.9703 | 3.9703 | 190.09 | 113.71 | 74.73 | 74.73 | 1 | 0 | 1.64 | 0.000028 | 0.000028 | 0.028823 | 0.028823 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 4.0466 | 4.0466 | 197.72 | 146.40 | 76.17 | 76.17 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033052 | 0.033052 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 4.0466 | 4.0466 | 190.42 | 190.42 | 76.17 | 76.17 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033052 | 0.033052 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 4.2616 | 4.2616 | 248.76 | 149.88 | 80.22 | 80.22 | 2 | 1 | 1.28 | 0.000028 | 0.000028 | 0.039156 | 0.039156 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.9600 | 3.9600 | 171.90 | 100.77 | 66.67 | 66.67 | 4 | 10 | 1.64 | 0.000028 | 0.000028 | 0.028446 | 0.028446 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.9496 | 3.9496 | 153.88 | 101.96 | 66.49 | 66.49 | 2 | 10 | 1.28 | 0.000028 | 0.000028 | 0.027436 | 0.027436 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 4.1056 | 4.1056 | 203.54 | 203.54 | 69.12 | 69.12 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.034567 | 0.034567 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.7383 | 3.7383 | 104.77 | 69.85 | 54.51 | 54.51 | 1 | 0 | 1.64 | 0.000028 | 0.000028 | 0.018944 | 0.018944 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.8827 | 3.8827 | 111.59 | 111.59 | 56.61 | 56.61 | 2 | 1 | 1.28 | 0.000028 | 0.000028 | 0.023934 | 0.023934 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5932 | 3.5932 | 39.38 | 39.38 | 42.78 | 42.78 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.013574 | 0.013574 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5752 | 3.5752 | 51.94 | 51.94 | 30.10 | 30.10 | 3 | 0 | 1.28 | 0.000028 | 0.000028 | 0.014640 | 0.014640 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6540 | 4.6540 | 698.32 | 698.32 | 137.30 | 137.30 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.053600 | 0.053600 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6217 | 4.6217 | 601.96 | 601.96 | 127.47 | 127.47 | 5 | 0 | 1.28 | 0.000005 | 0.000005 | 0.054428 | 0.054428 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6310 | 4.6310 | 555.41 | 555.41 | 122.45 | 122.45 | 19 | 0 | 1.28 | 0.000005 | 0.000005 | 0.050608 | 0.050608 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6128 | 4.6128 | 497.00 | 497.00 | 115.83 | 115.83 | 11 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051012 | 0.051012 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.4979 | 4.4979 | 373.03 | 373.03 | 100.35 | 100.35 | 10 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051765 | 0.051765 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4296 | 4.4296 | 301.31 | 301.31 | 90.19 | 90.19 | 3 | 0 | 1.28 | 0.000005 | 0.000005 | 0.049628 | 0.049628 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.2730 | 4.2730 | 151.55 | 151.55 | 63.96 | 63.96 | 3 | 0 | 1.28 | 0.000005 | 0.000005 | 0.040202 | 0.040202 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.9292 | 3.9292 | 57.14 | 57.14 | 39.27 | 39.27 | 1 | 0 | 1.28 | 0.000005 | 0.000005 | 0.023659 | 0.023659 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.2707 | 3.2707 | 20.56 | 20.56 | 23.56 | 23.56 | 1 | 0 | 1.28 | 0.000005 | 0.000005 | 0.007671 | 0.007671 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000037** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

## ANNUAL FREQUENCY OF COLLAPSE - SUMMARY (WATER ELEVATION 3.3 CD)

| Pier ID | Description | Ultimate Lateral Capacity, H (MN) | | Overall Annual Frequency of Collapse, AF | | | Return Period | % Risk |
|---|---|---|---|---|---|---|---|---|
| | | Foundation | Tower | Inbound | Outbound | Total | | |
| 1 | North Tower | **33** | **0** | 0.00000000 | 0.00000000 | 0.00000000 | - | 0% |
| 2 | South Tower | **173** | **0** | 0.00001640 | 0.00007349 | 0.00008988 | 11,126 | 100% |
| | | | **Total for Bridge:** | 0.00001640 | 0.00007349 | 0.00008988 | **11,126** | **100%** |

**Bridge Type:** **Class I**

**Minimum Return Period:** **10,000**

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# VESSEL FLEET CHARACTERISTICS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Size (m) | | Vessel Drafts (m) | | | | Vessel Displacement (tonnes) | | Channel Width, C (m) | Centerline Vessel Transit Path to Edge of Channel, $x_C$ (m) | | | | Minimum Design Impact Speed, $V_{min}$ (m/sec) | Standard Deviation, σ (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length Overall, LOA | Beam, B | Operational Loaded, $D_O$ | Ballasted | | | Loaded, $W_L$ | Ballasted, $W_E$ | | Inbound | | Outbound | | | Loaded | Ballasted |
| | | | | | | | Stern, $D_{ES}$ | Bow, $D_{EB}$ | Average, $D_{AVG}$ | | | | Pier 1 | Pier 2 | Pier 1 | Pier 2 | | | |
| 1 | Ship | Bulk Carrier | 210,000 | 300 | 50 | 15.0 | 9.2 | 5.0 | 7.1 | 180,650 | 85,510 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 2 | Ship | Bulk Carrier | 205,000 | 300 | 50 | 15.0 | 10.0 | 5.8 | 7.9 | 180,670 | 95,160 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 3 | Ship | Bulk Carrier | 185,000 | 292 | 45 | 15.0 | 10.2 | 6.1 | 8.2 | 158,000 | 85,850 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 292 | 292 |
| 4 | Ship | Bulk Carrier | 180,000 | 292 | 45 | 12.3 | 10.4 | 6.3 | 8.4 | 129,390 | 87,840 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 292 | 292 |
| 5 | Ship | Bulk Carrier | 175,000 | 289 | 45 | 12.6 | 9.5 | 5.4 | 7.5 | 130,940 | 77,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 289 | 289 |
| 6 | Ship | Bulk Carrier | 170,000 | 288 | 44 | 14.5 | 10.1 | 6.0 | 8.1 | 146,610 | 81,390 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 288 | 288 |
| 7 | Ship | Bulk Carrier | 165,000 | 288 | 44 | 15.0 | 10.0 | 5.9 | 8.0 | 151,460 | 80,280 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 288 | 288 |
| 8 | Ship | Bulk Carrier | 155,000 | 273 | 46 | 15.0 | 9.6 | 5.7 | 7.7 | 149,850 | 76,430 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 273 | 273 |
| 9 | Ship | Bulk Carrier | 150,000 | 269 | 43 | 15.0 | 10.0 | 6.2 | 8.1 | 137,740 | 74,380 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 269 | 269 |
| 10 | Ship | Tanker | 120,000 | 250 | 44 | 11.9 | 8.2 | 4.7 | 6.5 | 101,270 | 54,890 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 250 |
| 11 | Ship | Bulk Carrier | 120,000 | 254 | 43 | 14.5 | 7.6 | 4.0 | 5.8 | 124,980 | 50,000 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 254 | 254 |
| 12 | Ship | Container | 120,000 | 324 | 48 | 12.6 | 12.6 | 12.6 | 12.6 | 120,230 | 120,230 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 324 | 324 |
| 13 | Ship | Tanker | 115,000 | 250 | 44 | 11.9 | 9.3 | 5.8 | 7.6 | 101,120 | 64,160 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 250 |
| 14 | Ship | Bulk Carrier | 115,000 | 254 | 43 | 14.7 | 8.1 | 4.5 | 6.3 | 126,740 | 54,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 254 | 254 |
| 15 | Ship | Container | 115,000 | 300 | 48 | 11.9 | 11.9 | 11.9 | 11.9 | 105,070 | 105,070 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 16 | Ship | Tanker | 110,000 | 240 | 44 | 11.8 | 8.3 | 4.9 | 6.6 | 95,920 | 53,650 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 240 |
| 17 | Ship | Bulk Carrier | 110,000 | 255 | 43 | 12.3 | 8.2 | 4.6 | 6.4 | 106,510 | 55,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 255 | 255 |
| 18 | Ship | Container | 110,000 | 334 | 43 | 12.3 | 12.3 | 12.3 | 12.3 | 108,560 | 108,560 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 334 | 334 |
| 19 | Ship | Tanker | 105,000 | 244 | 42 | 13.0 | 8.4 | 5.0 | 6.7 | 102,480 | 52,820 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 244 |
| 20 | Ship | Bulk Carrier | 105,000 | 235 | 43 | 14.0 | 8.3 | 5.0 | 6.7 | 111,780 | 53,100 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 235 | 235 |
| 21 | Ship | Container | 105,000 | 335 | 43 | 12.6 | 12.6 | 12.6 | 12.6 | 111,550 | 111,550 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 335 | 335 |
| 22 | Ship | Bulk Carrier | 100,000 | 235 | 38 | 13.5 | 7.8 | 4.5 | 6.2 | 95,280 | 43,410 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 235 | 235 |
| 23 | Ship | Container | 100,000 | 338 | 46 | 12.8 | 12.8 | 12.8 | 12.8 | 122,370 | 122,370 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 338 | 338 |
| 24 | Ship | Bulk Carrier | 95,000 | 229 | 38 | 12.8 | 8.9 | 5.7 | 7.3 | 88,020 | 50,200 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 25 | Ship | Container | 95,000 | 320 | 46 | 13.6 | 13.6 | 13.6 | 13.6 | 122,750 | 122,750 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 320 | 320 |
| 26 | Ship | Bulk Carrier | 90,000 | 229 | 38 | 12.6 | 8.5 | 5.3 | 6.9 | 86,760 | 47,510 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 27 | Ship | Bulk Carrier | 85,000 | 229 | 32 | 12.7 | 8.2 | 5.0 | 6.6 | 73,730 | 38,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 28 | Ship | Container | 85,000 | 300 | 40 | 12.0 | 12.0 | 12.0 | 12.0 | 88,300 | 88,300 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 300 | 300 |
| 29 | Ship | Bulk Carrier | 80,000 | 225 | 32 | 12.3 | 7.7 | 4.5 | 6.1 | 70,180 | 34,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 225 | 225 |
| 30 | Ship | Container | 80,000 | 300 | 42 | 12.1 | 12.1 | 12.1 | 12.1 | 93,480 | 93,480 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 300 | 300 |
| 31 | Ship | Tanker | 75,000 | 228 | 34 | 11.3 | 8.3 | 5.1 | 6.7 | 66,730 | 39,570 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 228 |
| 32 | Ship | Bulk Carrier | 75,000 | 225 | 32 | 12.1 | 7.8 | 4.6 | 6.2 | 68,640 | 35,180 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 225 | 225 |
| 33 | Ship | Container | 75,000 | 293 | 40 | 12.3 | 12.3 | 12.3 | 12.3 | 88,600 | 88,600 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 293 | 293 |
| 34 | Ship | Tanker | 70,000 | 228 | 32 | 11.0 | 7.4 | 4.2 | 5.8 | 62,330 | 32,870 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 228 |
| 35 | Ship | Bulk Carrier | 70,000 | 199 | 36 | 12.2 | 6.5 | 3.7 | 5.1 | 68,720 | 28,730 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 199 | 199 |
| 36 | Ship | Container | 70,000 | 285 | 40 | 11.6 | 11.6 | 11.6 | 11.6 | 81,160 | 81,160 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 37 | Ship | Tanker | 65,000 | 214 | 32 | 10.9 | 7.5 | 4.5 | 6.0 | 57,520 | 31,660 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 73 | 214 |
| 38 | Ship | Bulk Carrier | 65,000 | 200 | 32 | 11.8 | 7.3 | 4.5 | 5.9 | 58,740 | 29,370 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 39 | Ship | Container | 65,000 | 285 | 38 | 12.2 | 12.2 | 12.2 | 12.2 | 79,180 | 79,180 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 40 | Ship | Bulk Carrier | 60,000 | 190 | 32 | 11.6 | 7.2 | 4.5 | 5.9 | 54,690 | 27,580 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 190 | 190 |
| 41 | Ship | General Cargo | 60,000 | 200 | 33 | 11.0 | 11.0 | 11.0 | 11.0 | 49,840 | 49,840 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 42 | Ship | Container | 60,000 | 268 | 35 | 12.0 | 12.0 | 12.0 | 12.0 | 75,320 | 75,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 268 | 268 |
| 43 | Ship | Tanker | 55,000 | 184 | 32 | 11.4 | 8.3 | 5.7 | 7.0 | 51,250 | 31,470 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 184 |
| 44 | Ship | Bulk Carrier | 55,000 | 190 | 32 | 11.0 | 7.1 | 4.4 | 5.8 | 51,680 | 27,020 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 190 | 190 |
| 45 | Ship | General Cargo | 55,000 | 200 | 32 | 8.2 | 8.2 | 8.2 | 8.2 | 36,030 | 36,030 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 46 | Ship | Tanker | 50,000 | 183 | 32 | 10.6 | 8.2 | 5.6 | 6.9 | 47,500 | 30,920 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 183 |
| 47 | Ship | Bulk Carrier | 50,000 | 192 | 32 | 10.1 | 7.4 | 4.7 | 6.1 | 47,810 | 28,640 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 192 | 192 |
| 48 | Ship | General Cargo | 50,000 | 200 | 31 | 10.9 | 10.9 | 10.9 | 10.9 | 46,390 | 46,390 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 49 | Ship | Container | 50,000 | 259 | 32 | 11.3 | 11.3 | 11.3 | 11.3 | 59,010 | 59,010 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 259 | 259 |

# VESSEL FLEET CHARACTERISTICS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Size (m) | | Vessel Drafts (m) | | | | Vessel Displacement (tonnes) | | Channel Width, C (m) | Centerline Vessel Transit Path to Edge of Channel, $x_C$ (m) | | | | Minimum Design Impact Speed, $V_{min}$ (m/sec) | Standard Deviation, σ (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length Overall, LOA | Beam, B | Operational Loaded, $D_O$ | Ballasted | | | Loaded, $W_L$ | Ballasted, $W_E$ | | Inbound | | Outbound | | | Loaded | Ballasted |
| | | | | | | | Stern, $D_{ES}$ | Bow, $D_{EB}$ | Average, $D_{AVG}$ | | | | Pier 1 | Pier 2 | Pier 1 | Pier 2 | | | |
| 50 | Ship | Tanker | 45,000 | 181 | 32 | 10.3 | 8.6 | 6.1 | 7.4 | 45,340 | 32,350 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 181 |
| 51 | Ship | Bulk Carrier | 45,000 | 188 | 29 | 10.3 | 6.9 | 4.3 | 5.6 | 43,080 | 23,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 188 | 188 |
| 52 | Ship | General Cargo | 45,000 | 187 | 29 | 10.1 | 10.1 | 10.1 | 10.1 | 37,670 | 37,670 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 187 | 187 |
| 53 | Ship | Tanker | 40,000 | 179 | 28 | 10.1 | 7.5 | 5.0 | 6.3 | 38,430 | 23,780 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 70 | 179 |
| 54 | Ship | Bulk Carrier | 40,000 | 180 | 30 | 9.6 | 6.6 | 4.1 | 5.4 | 39,540 | 22,040 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 55 | Ship | General Cargo | 40,000 | 180 | 30 | 9.6 | 9.6 | 9.6 | 9.6 | 35,590 | 35,590 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 56 | Ship | Tanker | 35,000 | 173 | 27 | 10.2 | 7.3 | 4.9 | 6.1 | 35,600 | 21,290 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 173 | 173 |
| 57 | Ship | Bulk Carrier | 35,000 | 180 | 30 | 9.3 | 6.4 | 3.9 | 5.2 | 37,960 | 21,020 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 58 | Ship | General Cargo | 35,000 | 180 | 28 | 6.7 | 6.7 | 6.7 | 6.7 | 23,250 | 23,250 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 59 | Ship | Container | 35,000 | 209 | 30 | 9.3 | 9.3 | 9.3 | 9.3 | 34,600 | 34,600 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 209 | 209 |
| 60 | Ship | Tanker | 30,000 | 159 | 27 | 9.2 | 6.5 | 4.3 | 5.4 | 29,160 | 17,120 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 159 | 159 |
| 61 | Ship | Bulk Carrier | 30,000 | 170 | 27 | 9.6 | 5.8 | 3.4 | 4.6 | 33,110 | 15,870 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 170 | 170 |
| 62 | Ship | General Cargo | 30,000 | 166 | 27 | 9.7 | 9.7 | 9.7 | 9.7 | 29,990 | 29,990 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 166 | 166 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 210 | 23 | 9.3 | 5.0 | 5.0 | 5.0 | 32,470 | 17,460 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 210 | 210 |
| 64 | Ship | Tanker | 25,000 | 146 | 24 | 9.2 | 6.5 | 4.5 | 5.5 | 22,970 | 13,740 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 146 | 146 |
| 65 | Ship | Bulk Carrier | 25,000 | 154 | 26 | 7.7 | 6.8 | 4.6 | 5.7 | 23,000 | 17,030 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 154 | 154 |
| 66 | Ship | General Cargo | 25,000 | 154 | 26 | 8.1 | 8.1 | 8.1 | 8.1 | 22,150 | 22,150 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 154 | 154 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 184 | 24 | 8.3 | 5.0 | 5.0 | 5.0 | 26,090 | 15,720 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 184 | 184 |
| 68 | Ship | Tanker | 20,000 | 145 | 24 | 8.7 | 6.1 | 4.1 | 5.1 | 20,880 | 12,240 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 145 | 145 |
| 69 | Ship | Bulk Carrier | 20,000 | 144 | 23 | 7.7 | 6.1 | 4.1 | 5.1 | 18,790 | 12,450 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 144 | 144 |
| 70 | Ship | General Cargo | 20,000 | 161 | 25 | 8.5 | 8.5 | 8.5 | 8.5 | 23,000 | 23,000 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 161 | 161 |
| 71 | Ship | Tanker | 15,000 | 127 | 20 | 8.1 | 6.3 | 4.5 | 5.4 | 14,280 | 9,520 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 127 | 127 |
| 72 | Ship | General Cargo | 15,000 | 138 | 21 | 7.2 | 7.2 | 7.2 | 7.2 | 14,100 | 14,100 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 138 | 138 |
| 73 | Ship | General Cargo | 10,000 | 118 | 16 | 4.5 | 4.5 | 4.5 | 4.5 | 5,810 | 5,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 118 | 118 |
| 74 | Ship | General Cargo | 5,000 | 117 | 20 | 4.7 | 4.7 | 4.7 | 4.7 | 7,740 | 7,740 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 117 | 117 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 317 | 37 | 8.3 | 8.3 | 8.3 | 8.3 | 61,410 | 61,410 | 142.0 | 93.5 | 48.5 | 57.0 | 85.0 | 2.57 | 317 | 317 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 290 | 36 | 8.5 | 8.5 | 8.5 | 8.5 | 53,680 | 53,680 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 290 | 290 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 294 | 32 | 8.6 | 8.6 | 8.6 | 8.6 | 49,330 | 49,330 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 294 | 294 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 285 | 32 | 8.0 | 8.0 | 8.0 | 8.0 | 44,490 | 44,490 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 240 | 32 | 8.1 | 8.1 | 8.1 | 8.1 | 35,120 | 35,120 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 240 | 240 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 220 | 31 | 7.7 | 7.7 | 7.7 | 7.7 | 29,250 | 29,250 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 220 | 220 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 186 | 25 | 6.1 | 6.1 | 6.1 | 6.1 | 15,810 | 15,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 186 | 186 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 142 | 18 | 4.9 | 4.9 | 4.9 | 4.9 | 7,050 | 7,050 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 142 | 142 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 103 | 15 | 4.1 | 4.1 | 4.1 | 4.1 | 3,660 | 3,660 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 103 | 103 |

**Notes:**

Weight of Water ($W_W$) = **0.9854** $m^3$/tonne (used to determine ship loaded/ballasted displacement tonnage based on approximate salinity of water in Vancouver Harbor)

# VESSEL FLEET ANNUAL TRIP FREQUENCY

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Annual Number of Trips (N) | | | | | | Existing Total Trips | Growth Factor [1] | Future Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | | Outbound | | | | | |
| | | | | Loaded | Ballasted | Total | Loaded | Ballasted | Total | | | |
| 1 | Ship | Bulk Carrier | 210,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 2 | Ship | Bulk Carrier | 205,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 1.28 | 3 |
| 3 | Ship | Bulk Carrier | 185,000 | 0 | 2 | 2 | 0 | 2 | 2 | 4 | 1.28 | 5 |
| 4 | Ship | Bulk Carrier | 180,000 | 0 | 2 | 2 | 1 | 1 | 2 | 4 | 1.28 | 5 |
| 5 | Ship | Bulk Carrier | 175,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 6 | Ship | Bulk Carrier | 170,000 | 1 | 1 | 2 | 0 | 1 | 1 | 3 | 1.28 | 4 |
| 7 | Ship | Bulk Carrier | 165,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 8 | Ship | Bulk Carrier | 155,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 9 | Ship | Bulk Carrier | 150,000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 10 | Ship | Tanker | 120,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 10.20 | 41 |
| 11 | Ship | Bulk Carrier | 120,000 | 0 | 1 | 1 | 1 | 1 | 2 | 3 | 1.28 | 4 |
| 12 | Ship | Container | 120,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 13 | Ship | Tanker | 115,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10.20 | 0 |
| 14 | Ship | Bulk Carrier | 115,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 15 | Ship | Container | 115,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 16 | Ship | Tanker | 110,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 10.20 | 41 |
| 17 | Ship | Bulk Carrier | 110,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 18 | Ship | Container | 110,000 | 2 | 0 | 2 | 1 | 0 | 1 | 3 | 1.28 | 4 |
| 19 | Ship | Tanker | 105,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10.20 | 0 |
| 20 | Ship | Bulk Carrier | 105,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 21 | Ship | Container | 105,000 | 4 | 0 | 4 | 5 | 0 | 5 | 9 | 1.28 | 12 |
| 22 | Ship | Bulk Carrier | 100,000 | 0 | 2 | 2 | 1 | 0 | 1 | 3 | 1.28 | 4 |
| 23 | Ship | Container | 100,000 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 1.28 | 28 |
| 24 | Ship | Bulk Carrier | 95,000 | 0 | 5 | 5 | 3 | 3 | 6 | 11 | 1.28 | 14 |
| 25 | Ship | Container | 95,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 26 | Ship | Bulk Carrier | 90,000 | 1 | 4 | 5 | 2 | 2 | 4 | 9 | 1.28 | 12 |
| 27 | Ship | Bulk Carrier | 85,000 | 6 | 39 | 45 | 30 | 16 | 46 | 91 | 1.28 | 116 |
| 28 | Ship | Container | 85,000 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 29 | Ship | Bulk Carrier | 80,000 | 8 | 34 | 42 | 29 | 12 | 41 | 83 | 1.28 | 106 |
| 30 | Ship | Container | 80,000 | 9 | 0 | 9 | 9 | 0 | 9 | 18 | 1.28 | 23 |
| 31 | Ship | Tanker | 75,000 | 0 | 1 | 1 | 2 | 0 | 2 | 3 | 1.64 | 5 |
| 32 | Ship | Bulk Carrier | 75,000 | 2 | 13 | 15 | 9 | 6 | 15 | 30 | 1.28 | 38 |
| 33 | Ship | Container | 75,000 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 1.28 | 28 |
| 34 | Ship | Tanker | 70,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.64 | 0 |
| 35 | Ship | Bulk Carrier | 70,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 36 | Ship | Container | 70,000 | 30 | 0 | 30 | 30 | 0 | 30 | 60 | 1.28 | 77 |
| 37 | Ship | Tanker | 65,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 38 | Ship | Bulk Carrier | 65,000 | 14 | 36 | 50 | 35 | 15 | 50 | 100 | 1.28 | 128 |
| 39 | Ship | Container | 65,000 | 8 | 0 | 8 | 8 | 0 | 8 | 16 | 1.28 | 20 |
| 40 | Ship | Bulk Carrier | 60,000 | 12 | 43 | 55 | 45 | 11 | 56 | 111 | 1.28 | 142 |
| 41 | Ship | General Cargo | 60,000 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 42 | Ship | Container | 60,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 43 | Ship | Tanker | 55,000 | 1 | 2 | 3 | 2 | 0 | 2 | 5 | 1.64 | 8 |
| 44 | Ship | Bulk Carrier | 55,000 | 1 | 8 | 9 | 6 | 3 | 9 | 18 | 1.28 | 23 |
| 45 | Ship | General Cargo | 55,000 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| 46 | Ship | Tanker | 50,000 | 4 | 8 | 12 | 8 | 4 | 12 | 24 | 1.64 | 39 |
| 47 | Ship | Bulk Carrier | 50,000 | 1 | 3 | 4 | 3 | 1 | 4 | 8 | 1.28 | 10 |
| 48 | Ship | General Cargo | 50,000 | 6 | 6 | 12 | 6 | 6 | 12 | 24 | 1.28 | 31 |
| 49 | Ship | Container | 50,000 | 1 | 0 | 1 | 2 | 0 | 2 | 3 | 1.28 | 4 |

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# VESSEL FLEET ANNUAL TRIP FREQUENCY

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Annual Number of Trips (N) | | | | | | Existing Total Trips | Growth Factor [1] | Future Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | | Outbound | | | | | |
| | | | | Loaded | Ballasted | Total | Loaded | Ballasted | Total | | | |
| 50 | Ship | Tanker | 45,000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1.64 | 2 |
| 51 | Ship | Bulk Carrier | 45,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 52 | Ship | General Cargo | 45,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 53 | Ship | Tanker | 40,000 | 1 | 5 | 6 | 5 | 1 | 6 | 12 | 1.64 | 20 |
| 54 | Ship | Bulk Carrier | 40,000 | 5 | 19 | 24 | 19 | 6 | 25 | 49 | 1.28 | 63 |
| 55 | Ship | General Cargo | 40,000 | 2 | 7 | 9 | 6 | 1 | 7 | 16 | 1.28 | 20 |
| 56 | Ship | Tanker | 35,000 | 1 | 2 | 3 | 2 | 1 | 3 | 6 | 1.64 | 10 |
| 57 | Ship | Bulk Carrier | 35,000 | 6 | 13 | 19 | 14 | 6 | 20 | 39 | 1.28 | 50 |
| 58 | Ship | General Cargo | 35,000 | 5 | 11 | 16 | 11 | 5 | 16 | 32 | 1.28 | 41 |
| 59 | Ship | Container | 35,000 | 7 | 0 | 7 | 7 | 0 | 7 | 14 | 1.28 | 18 |
| 60 | Ship | Tanker | 30,000 | 0 | 7 | 7 | 7 | 0 | 7 | 14 | 1.64 | 23 |
| 61 | Ship | Bulk Carrier | 30,000 | 2 | 11 | 13 | 10 | 4 | 14 | 27 | 1.28 | 35 |
| 62 | Ship | General Cargo | 30,000 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 2 | 5 | 7 | 5 | 2 | 7 | 14 | 1.28 | 18 |
| 64 | Ship | Tanker | 25,000 | 1 | 1 | 2 | 1 | 1 | 2 | 4 | 1.64 | 7 |
| 65 | Ship | Bulk Carrier | 25,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 66 | Ship | General Cargo | 25,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 2 | 2 | 4 | 2 | 1 | 3 | 7 | 1.28 | 9 |
| 68 | Ship | Tanker | 20,000 | 9 | 4 | 13 | 5 | 10 | 15 | 28 | 1.64 | 46 |
| 69 | Ship | Bulk Carrier | 20,000 | 10 | 2 | 12 | 2 | 9 | 11 | 23 | 1.28 | 29 |
| 70 | Ship | General Cargo | 20,000 | 2 | 0 | 2 | 1 | 0 | 1 | 3 | 1.28 | 4 |
| 71 | Ship | Tanker | 15,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 72 | Ship | General Cargo | 15,000 | 1 | 1 | 2 | 2 | 2 | 4 | 6 | 1.28 | 8 |
| 73 | Ship | General Cargo | 10,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 74 | Ship | General Cargo | 5,000 | 3 | 0 | 3 | 2 | 0 | 2 | 5 | 1.28 | 6 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1.28 | 13 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 19 | 0 | 19 | 19 | 0 | 19 | 38 | 1.28 | 49 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 11 | 0 | 11 | 10 | 0 | 10 | 21 | 1.28 | 27 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 1.28 | 28 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 2 | 0 | 2 | 3 | 0 | 3 | 5 | 1.28 | 6 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| | | **Total Trips:** | | 255 | 312 | 567 | 433 | 134 | 567 | 1134 | | 1561 |

**Notes:**

[1] As part of the risk analysis, vessel trips will include future growth in the waterway that are projected to the mid-point of the remaining design life (assumed 50 years) of the structure. This equates to growth rates per year as follows for a 25-year projection. GF = $(1+\text{PERCENT}/100)^{25}$

- Aframax Tankers (DWT greater than 100,000 tonnes) = 9.735%
- All Other Tankers = 2.0%
- All Other Vessels = 1.0%

# VESSEL FLEET TRANSIT SPEEDS IN MAIN CHANNEL

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Transit Speeds (knots) | | | | Vessel Transit Speeds (m/sec) [1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | Outbound | | Inbound | | Outbound | |
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted |
| 1 | Ship | Bulk Carrier | 210,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 2 | Ship | Bulk Carrier | 205,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 3 | Ship | Bulk Carrier | 185,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 4 | Ship | Bulk Carrier | 180,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 5 | Ship | Bulk Carrier | 175,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 6 | Ship | Bulk Carrier | 170,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 7 | Ship | Bulk Carrier | 165,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 8 | Ship | Bulk Carrier | 155,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 9 | Ship | Bulk Carrier | 150,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 10 | Ship | Tanker | 120,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 11 | Ship | Bulk Carrier | 120,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 12 | Ship | Container | 120,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 13 | Ship | Tanker | 115,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 14 | Ship | Bulk Carrier | 115,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 15 | Ship | Container | 115,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 16 | Ship | Tanker | 110,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 17 | Ship | Bulk Carrier | 110,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 18 | Ship | Container | 110,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 19 | Ship | Tanker | 105,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 20 | Ship | Bulk Carrier | 105,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 21 | Ship | Container | 105,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 22 | Ship | Bulk Carrier | 100,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 23 | Ship | Container | 100,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 24 | Ship | Bulk Carrier | 95,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 25 | Ship | Container | 95,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 26 | Ship | Bulk Carrier | 90,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 27 | Ship | Bulk Carrier | 85,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 28 | Ship | Container | 85,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 29 | Ship | Bulk Carrier | 80,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 30 | Ship | Container | 80,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 31 | Ship | Tanker | 75,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 32 | Ship | Bulk Carrier | 75,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 33 | Ship | Container | 75,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 34 | Ship | Tanker | 70,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 35 | Ship | Bulk Carrier | 70,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 36 | Ship | Container | 70,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 37 | Ship | Tanker | 65,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 38 | Ship | Bulk Carrier | 65,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 39 | Ship | Container | 65,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 40 | Ship | Bulk Carrier | 60,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 41 | Ship | General Cargo | 60,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 42 | Ship | Container | 60,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 43 | Ship | Tanker | 55,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 44 | Ship | Bulk Carrier | 55,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 45 | Ship | General Cargo | 55,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 46 | Ship | Tanker | 50,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 47 | Ship | Bulk Carrier | 50,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 48 | Ship | General Cargo | 50,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 49 | Ship | Container | 50,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |

# VESSEL FLEET TRANSIT SPEEDS IN MAIN CHANNEL

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Transit Speeds (knots) | | | | Vessel Transit Speeds (m/sec) [1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | Outbound | | Inbound | | Outbound | |
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted |
| 50 | Ship | Tanker | 45,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 51 | Ship | Bulk Carrier | 45,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 52 | Ship | General Cargo | 45,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 53 | Ship | Tanker | 40,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 54 | Ship | Bulk Carrier | 40,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 55 | Ship | General Cargo | 40,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 56 | Ship | Tanker | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 57 | Ship | Bulk Carrier | 35,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 58 | Ship | General Cargo | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 59 | Ship | Container | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 60 | Ship | Tanker | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 61 | Ship | Bulk Carrier | 30,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 62 | Ship | General Cargo | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 64 | Ship | Tanker | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 65 | Ship | Bulk Carrier | 25,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 66 | Ship | General Cargo | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 68 | Ship | Tanker | 20,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 69 | Ship | Bulk Carrier | 20,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 70 | Ship | General Cargo | 20,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 71 | Ship | Tanker | 15,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 72 | Ship | General Cargo | 15,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 73 | Ship | General Cargo | 10,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 74 | Ship | General Cargo | 5,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |

**Notes:**

[1] Conversion (knot to m/sec) = 0.51 (convert vessel transit speeds from knots to meters/second for use in risk assessment equations)

# ABERRANCY BASE RATE COMPUTATIONS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Code Recommended Aberrancy Base Rate, BR | Vessel Traffic Service, VTS | Electronic Chart Display & Information System, ECDIS | Other Navigation Aids | Port Control State, PCS | Pilotage 1 Pilot | Pilotage 2 Pilots (MRA-2) | | Daytime Only Transit Restrictions (MRA-2) | Visibility Restrictions (MRA-2) | Cruise Ship Considerations | Adjusted Aberrancy Base Rate, BR [1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Loaded | Ballasted | | | | Loaded | Ballasted |
| 1 | Ship | Bulk Carrier | 210,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 2 | Ship | Bulk Carrier | 205,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 3 | Ship | Bulk Carrier | 185,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 4 | Ship | Bulk Carrier | 180,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 5 | Ship | Bulk Carrier | 175,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 6 | Ship | Bulk Carrier | 170,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 7 | Ship | Bulk Carrier | 165,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 8 | Ship | Bulk Carrier | 155,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 9 | Ship | Bulk Carrier | 150,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 10 | Ship | Tanker | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 11 | Ship | Bulk Carrier | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 12 | Ship | Container | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 13 | Ship | Tanker | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 14 | Ship | Bulk Carrier | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 15 | Ship | Container | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 16 | Ship | Tanker | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 17 | Ship | Bulk Carrier | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 18 | Ship | Container | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 19 | Ship | Tanker | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 20 | Ship | Bulk Carrier | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 21 | Ship | Container | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 22 | Ship | Bulk Carrier | 100,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 23 | Ship | Container | 100,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 24 | Ship | Bulk Carrier | 95,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 25 | Ship | Container | 95,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 26 | Ship | Bulk Carrier | 90,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 27 | Ship | Bulk Carrier | 85,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 28 | Ship | Container | 85,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 29 | Ship | Bulk Carrier | 80,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 30 | Ship | Container | 80,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 31 | Ship | Tanker | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 32 | Ship | Bulk Carrier | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 33 | Ship | Container | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 34 | Ship | Tanker | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 35 | Ship | Bulk Carrier | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 36 | Ship | Container | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 37 | Ship | Tanker | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 38 | Ship | Bulk Carrier | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 39 | Ship | Container | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 40 | Ship | Bulk Carrier | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 41 | Ship | General Cargo | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 42 | Ship | Container | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 43 | Ship | Tanker | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 44 | Ship | Bulk Carrier | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 45 | Ship | General Cargo | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 46 | Ship | Tanker | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 47 | Ship | Bulk Carrier | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 48 | Ship | General Cargo | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 49 | Ship | Container | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |

# ABERRANCY BASE RATE COMPUTATIONS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Code Recommended Aberrancy Base Rate, BR | Vessel Traffic Service, VTS | Electronic Chart Display & Information System, ECDIS | Other Navigation Aids | Port Control State, PCS | Pilotage 1 Pilot | Pilotage 2 Pilots (MRA-2) | | Daytime Only Transit Restrictions (MRA-2) | Visibility Restrictions (MRA-2) | Cruise Ship Considerations | Adjusted Aberrancy Base Rate, BR [1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Loaded | Ballasted | | | | Loaded | Ballasted |
| 50 | Ship | Tanker | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 51 | Ship | Bulk Carrier | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 52 | Ship | General Cargo | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 53 | Ship | Tanker | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 54 | Ship | Bulk Carrier | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 55 | Ship | General Cargo | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 56 | Ship | Tanker | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 57 | Ship | Bulk Carrier | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 58 | Ship | General Cargo | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 59 | Ship | Container | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 60 | Ship | Tanker | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 61 | Ship | Bulk Carrier | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 62 | Ship | General Cargo | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 64 | Ship | Tanker | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 65 | Ship | Bulk Carrier | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 66 | Ship | General Cargo | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 68 | Ship | Tanker | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 69 | Ship | Bulk Carrier | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 70 | Ship | General Cargo | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 71 | Ship | Tanker | 15,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 72 | Ship | General Cargo | 15,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 73 | Ship | General Cargo | 10,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 74 | Ship | General Cargo | 5,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |

**Notes:**

[1] Adjustments to the aberrancy Base Rate (BR) due to waterway current restrictions are accounted for elsewhere in the vessel collision risk analysis (refer to correction factors $R_C$ and $R_{XC}$ for the Probability of Aberrancy at each transit leg).

# MISCELLANEOUS INFORMATION

## CHANNEL CHARACTERISTICS

| | | |
|---|---|---|
| Waterway Current Speed ($V_{min}$) = | **2.57** | m/sec |
| Water Elevation = | **3.30** | m (based on Chart Datum) |
| Sea Level Rise Adjustment = | **0.10** | m |
| Soft Soil Allowance = | **2.00** | m (assumed depth that vessels can "plow" through soft bottom material or "ride up" on underlying rock) |

## AVAILABLE WATER DEPTH AT PIERS

| Pier ID | Description | Mudline Elevation (m) [1] | | Water Elevation (m) | Soft Soil Allowance (m) | Design Water Depth (m) | |
|---|---|---|---|---|---|---|---|
| | | Inbound | Outbound | | | Inbound | Outbound |
| **1** | **North Tower** | **5.00** | **5.00** | 3.40 | 2.00 | 0.40 | 0.40 |
| **2** | **South Tower** | **-7.00** | **-7.00** | 3.40 | 2.00 | 12.40 | 12.40 |

**Notes:**

[1] Mudline elevation is based on Chart Datum (CD) and was obtained from Nautical Chart 3493

## PROBABILITY OF ABERRANCY VARIABLES FOR EACH VESSEL TRANSIT PATH

| Leg ID | Waterway Region for Bridge Location | Angle of Channel Turn, θ (deg) [1] | Correction Factor, $R_B$ | Current Angle to Vessel Path (deg) [2] | Parallel Current, $V_C$ (m/sec) | Perpendicular Current, $V_{XC}$ (m/sec) | Correction Factor, $R_C$ | Correction Factor, $R_{XC}$ | Vessel Traffic Density | Correction Factor, $R_D$ | Summation ($R_B$*$R_C$*$R_{XC}$*$R_D$) | Aberrancy Distribution [3] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Inbound | Outbound |
| **1** | **Transition** | **44.4795** | 1.4942 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 2.2622 | **0.16** | **N/A** |
| **2** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.40** | **N/A** |
| **3** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.22** | **N/A** |
| **4** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.22** | **N/A** |
| **5** | **Transition** | **28.0177** | 1.3113 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 1.9853 | **N/A** | **0.50** |
| **6** | **Straight** | **0.0000** | 1.0000 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 1.5140 | **N/A** | **0.50** |

**Notes:**

[1] Angle of the turn region in accordance with information shown on Nautical Chart 3493, AIS transit data near the bridge, and CAN/CSA S6-14 Figure A3.3.1

[2] The angle between the water current direction and each channel transition leg

[3] Distribution of the Probability of Aberrancy for each channel transition leg is established as a ratio of the length of each leg to the overall length being considered (approximately 1 nautical mile or 2000m)

## GEOMETRIC PROBABILITY DISTANCES FOR NORMAL DISTRIBUTION

| Pier ID | Description | Leg 1 [1] | | | Leg 2 [1] | | | Leg 3 [1] | | | Leg 4 [1] | | | Leg 5 [1] | | | Leg 6 [1] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) |
| 1 | North Tower | **328.75** | 342.54 | **356.34** | **32.88** | 44.83 | **56.78** | **138.33** | 149.19 | **160.06** | **245.78** | 254.19 | **262.59** | **212.19** | 219.89 | **227.60** | **212.19** | 219.89 | **227.60** |
| 2 | South Tower | **684.04** | 701.58 | **719.11** | **356.33** | 371.76 | **387.18** | **274.04** | 288.34 | **302.64** | **197.61** | 209.61 | **221.61** | **239.38** | 250.07 | **260.76** | **239.38** | 250.07 | **260.76** |

**Notes:**

[1] Perpendicular distances at each channel transition leg from the centerline of vessel transit path to the bridge element being considered. Distance "x" is from the centerline of vessel transit path to the centerline of bridge element. Distance "$x_1$" (scaled from CADD drawing) is from the centerline of vessel transit path to the closest edge of the bridge element. Distance "$x_2$" (scaled from CADD drawing) is from the centerline of vessel transit path to the farthest edge of the bridge element.

## PROTECTION FACTOR

| Pier ID | Description | Leg 1 | | Leg 2 | | Leg 3 | | Leg 4 | | Leg 5 | | Leg 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound |
| 1 | North Tower | **0.62** | **N/A** | **0.54** | **N/A** | **0.43** | **N/A** | **0.33** | **N/A** | **N/A** | **0.18** | **N/A** | **0.18** |
| 2 | South Tower | **0.003** | **N/A** | **0.01** | **N/A** | **0.02** | **N/A** | **0.04** | **N/A** | **N/A** | **0.14** | **N/A** | **0.14** |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053804 | 0.053804 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053804 | 0.053804 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049883 | 0.049883 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049883 | 0.049883 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049686 | 0.049686 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048933 | 0.048933 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048933 | 0.048933 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049023 | 0.049023 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046613 | 0.046613 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000027 | 0.044813 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044769 | 0.044769 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053234 | 0.053234 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000027 | 0.044813 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044769 | 0.044769 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.052415 | 0.052415 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000023 | 0.043133 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044909 | 0.044909 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049831 | 0.049831 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000023 | 0.042606 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.041590 | 0.041590 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049838 | 0.049838 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.038622 | 0.038622 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.051971 | 0.051971 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.037482 | 0.037482 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.051743 | 0.051743 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.037482 | 0.037482 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.034028 | 0.034028 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046859 | 0.046859 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.033282 | 0.033282 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048248 | 0.048248 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000014 | 0.034704 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.033282 | 0.033282 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046498 | 0.046498 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000013 | 0.033846 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.029214 | 0.029214 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.045990 | 0.045990 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000010 | 0.031005 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027612 | 0.027612 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044626 | 0.044626 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.024857 | 0.024857 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.028082 | 0.028082 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.041220 | 0.041220 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.023082 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.024857 | 0.024857 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027612 | 0.027612 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.022778 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.025429 | 0.025429 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027142 | 0.027142 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.038337 | 0.038337 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.022163 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.023031 | 0.023031 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.022751 | 0.022751 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000004 | 0.020063 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.017939 | 0.017939 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.020355 | 0.020355 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.028844 | 0.028844 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.013690 | 0.013690 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.017043 | 0.017043 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.015832 | 0.015832 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.025304 | 0.025304 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.009200 | 0.009200 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011929 | 0.011929 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011929 | 0.011929 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.019930 | 0.019930 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.008924 | 0.008924 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.008474 | 0.008474 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.013763 | 0.013763 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.004079 | 0.004079 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006623 | 0.006623 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002272 | 0.002272 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002350 | 0.002350 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.045210 | 0.045210 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.043545 | 0.043545 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.041184 | 0.041184 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.040685 | 0.040685 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.035982 | 0.035982 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.031633 | 0.031633 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.020774 | 0.020774 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.007148 | 0.007148 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000709 | 0.000709 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] $PA = (BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096934 | 0.096934 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096934 | 0.096934 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092813 | 0.092813 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092813 | 0.092813 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.093749 | 0.093749 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092706 | 0.092706 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092706 | 0.092706 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100503 | 0.100503 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.097595 | 0.097595 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.293189 | 0.106299 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.103154 | 0.103154 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.087504 | 0.087504 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.293189 | 0.106299 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.103154 | 0.103154 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.094323 | 0.094323 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.294705 | 0.110550 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.102764 | 0.102764 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.079055 | 0.079055 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.285780 | 0.105624 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.111152 | 0.111152 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.078824 | 0.078824 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.102892 | 0.102892 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.081631 | 0.081631 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.105471 | 0.105471 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086118 | 0.086118 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.105471 | 0.105471 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.095298 | 0.095298 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.083869 | 0.083869 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096918 | 0.096918 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086484 | 0.086484 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.252373 | 0.098253 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096918 | 0.096918 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.085819 | 0.085819 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.245976 | 0.095698 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.116646 | 0.116646 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.088159 | 0.088159 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.248120 | 0.101661 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108392 | 0.108392 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.085410 | 0.085410 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.113752 | 0.113752 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.110319 | 0.110319 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086283 | 0.086283 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.253671 | 0.117220 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.113752 | 0.113752 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108392 | 0.108392 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.253883 | 0.117818 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.112639 | 0.112639 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.106464 | 0.106464 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.084655 | 0.084655 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.254313 | 0.119031 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108759 | 0.108759 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.109304 | 0.109304 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.237028 | 0.111720 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.113108 | 0.113108 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.111142 | 0.111142 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100269 | 0.100269 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.122241 | 0.122241 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.114954 | 0.114954 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.117506 | 0.117506 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086168 | 0.086168 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.124339 | 0.124339 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123397 | 0.123397 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123397 | 0.123397 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100539 | 0.100539 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.125108 | 0.125108 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123280 | 0.123280 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.116137 | 0.116137 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.128994 | 0.128994 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.122630 | 0.122630 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.124977 | 0.124977 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.138383 | 0.138383 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.075464 | 0.075464 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.081411 | 0.081411 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.075076 | 0.075076 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.077380 | 0.077380 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.091430 | 0.091430 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.096904 | 0.096904 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.101180 | 0.101180 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.111543 | 0.111543 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.137764 | 0.137764 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084140 | 0.084140 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084140 | 0.084140 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079884 | 0.079884 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079884 | 0.079884 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.080492 | 0.080492 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079490 | 0.079490 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079490 | 0.079490 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085092 | 0.085092 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082175 | 0.082175 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.054561 | 0.087617 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085406 | 0.085406 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077104 | 0.077104 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.054561 | 0.087617 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085406 | 0.085406 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081802 | 0.081802 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.053453 | 0.089890 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085187 | 0.085187 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069887 | 0.069887 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.052013 | 0.086279 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.089661 | 0.089661 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069720 | 0.069720 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082758 | 0.082758 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072423 | 0.072423 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084021 | 0.084021 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075631 | 0.075631 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084021 | 0.084021 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075604 | 0.075604 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072444 | 0.072444 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076364 | 0.076364 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074784 | 0.074784 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.042584 | 0.077904 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076364 | 0.076364 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.073729 | 0.073729 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.041288 | 0.075794 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.087244 | 0.087244 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075238 | 0.075238 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.039718 | 0.078448 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081036 | 0.081036 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072807 | 0.072807 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082780 | 0.082780 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082540 | 0.082540 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072232 | 0.072232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035639 | 0.083755 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082780 | 0.082780 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081036 | 0.081036 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035483 | 0.083911 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082441 | 0.082441 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079531 | 0.079531 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.070024 | 0.070024 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035166 | 0.084216 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078482 | 0.078482 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078636 | 0.078636 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.031893 | 0.078233 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.077409 | 0.077409 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078098 | 0.078098 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076437 | 0.076437 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.078688 | 0.078688 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077743 | 0.077743 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078142 | 0.078142 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065371 | 0.065371 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.074144 | 0.074144 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077314 | 0.077314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077314 | 0.077314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.071308 | 0.071308 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.074122 | 0.074122 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072472 | 0.072472 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075334 | 0.075334 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.065858 | 0.065858 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068904 | 0.068904 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057501 | 0.057501 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.063314 | 0.063314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.065831 | 0.065831 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.069576 | 0.069576 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.064239 | 0.064239 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.065719 | 0.065719 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.073799 | 0.073799 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.075591 | 0.075591 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.072279 | 0.072279 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.064298 | 0.064298 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.050670 | 0.050670 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062009 | 0.062009 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062009 | 0.062009 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057783 | 0.057783 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057783 | 0.057783 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057925 | 0.057925 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057033 | 0.057033 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057033 | 0.057033 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059479 | 0.059479 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056742 | 0.056742 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001520 | 0.057871 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056930 | 0.056930 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058620 | 0.058620 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001520 | 0.057871 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056930 | 0.056930 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060154 | 0.060154 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001408 | 0.057703 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056929 | 0.056929 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053443 | 0.053443 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001384 | 0.055894 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056588 | 0.056588 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053375 | 0.053375 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051853 | 0.051853 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055835 | 0.055835 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051593 | 0.051593 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057080 | 0.057080 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051593 | 0.051593 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045939 | 0.045939 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.052735 | 0.052735 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045739 | 0.045739 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.054590 | 0.054590 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000971 | 0.047305 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045739 | 0.045739 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053068 | 0.053068 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000932 | 0.045893 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.046908 | 0.046908 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053404 | 0.053404 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000810 | 0.044976 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043476 | 0.043476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051525 | 0.051525 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.041967 | 0.041967 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.044369 | 0.044369 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.049174 | 0.049174 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000549 | 0.040860 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.041967 | 0.041967 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043476 | 0.043476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000540 | 0.040660 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042301 | 0.042301 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042582 | 0.042582 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.046440 | 0.046440 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)



# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000523 | 0.040245 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.039047 | 0.039047 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038876 | 0.038876 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000449 | 0.036530 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.034430 | 0.034430 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.036732 | 0.036732 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042687 | 0.042687 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.030775 | 0.030775 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.033728 | 0.033728 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.032723 | 0.032723 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.036007 | 0.036007 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.024656 | 0.024656 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028555 | 0.028555 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028555 | 0.028555 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.034135 | 0.034135 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.024316 | 0.024316 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.023377 | 0.023377 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.029913 | 0.029913 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.015764 | 0.015764 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.020188 | 0.020188 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.011026 | 0.011026 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.012031 | 0.012031 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.048882 | 0.048882 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.049476 | 0.049476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.045738 | 0.045738 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.046068 | 0.046068 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.046500 | 0.046500 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.044314 | 0.044314 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.035138 | 0.035138 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.019839 | 0.019839 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.006060 | 0.006060 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062377 | 0.062377 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064824 | 0.064824 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061974 | 0.061974 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061956 | 0.061956 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064396 | 0.064396 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005333 | 0.064870 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062964 | 0.062964 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056126 | 0.056126 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005213 | 0.062504 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063975 | 0.063975 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056031 | 0.056031 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058501 | 0.058501 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058605 | 0.058605 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.060404 | 0.060404 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052072 | 0.052072 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056283 | 0.056283 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058312 | 0.058312 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003846 | 0.053737 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056884 | 0.056884 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003700 | 0.052089 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.055998 | 0.055998 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057551 | 0.057551 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003341 | 0.052129 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.055476 | 0.055476 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052781 | 0.052781 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.053560 | 0.053560 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002517 | 0.050382 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002488 | 0.050266 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051160 | 0.051160 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050598 | 0.050598 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050901 | 0.050901 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002431 | 0.050018 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047584 | 0.047584 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047491 | 0.047491 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002121 | 0.045543 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.043662 | 0.043662 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.045667 | 0.045667 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.049839 | 0.049839 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.040997 | 0.040997 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.043182 | 0.043182 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.042467 | 0.042467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.041733 | 0.041733 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.034767 | 0.034767 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.041865 | 0.041865 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.034467 | 0.034467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033286 | 0.033286 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.039483 | 0.039483 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.025001 | 0.025001 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.029700 | 0.029700 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.018840 | 0.018840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.020840 | 0.020840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051602 | 0.051602 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.053055 | 0.053055 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.048796 | 0.048796 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.049443 | 0.049443 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051992 | 0.051992 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.050842 | 0.050842 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.042904 | 0.042904 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.028412 | 0.028412 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.012379 | 0.012379 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062377 | 0.062377 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064824 | 0.064824 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061974 | 0.061974 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061956 | 0.061956 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064396 | 0.064396 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005333 | 0.064870 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062964 | 0.062964 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056126 | 0.056126 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005213 | 0.062504 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063975 | 0.063975 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056031 | 0.056031 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058501 | 0.058501 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058605 | 0.058605 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.060404 | 0.060404 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052072 | 0.052072 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056283 | 0.056283 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058312 | 0.058312 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003846 | 0.053737 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056884 | 0.056884 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003700 | 0.052089 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.055998 | 0.055998 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057551 | 0.057551 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003341 | 0.052129 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.055476 | 0.055476 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052781 | 0.052781 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.053560 | 0.053560 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002517 | 0.050382 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002488 | 0.050266 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051160 | 0.051160 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050598 | 0.050598 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050901 | 0.050901 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002431 | 0.050018 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047584 | 0.047584 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047491 | 0.047491 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002121 | 0.045543 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.043662 | 0.043662 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.045667 | 0.045667 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.049839 | 0.049839 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.040997 | 0.040997 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.043182 | 0.043182 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.042467 | 0.042467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.041733 | 0.041733 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.034767 | 0.034767 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.041865 | 0.041865 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.034467 | 0.034467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033286 | 0.033286 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.039483 | 0.039483 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.025001 | 0.025001 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.029700 | 0.029700 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.018840 | 0.018840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.020840 | 0.020840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051602 | 0.051602 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.053055 | 0.053055 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.048796 | 0.048796 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.049443 | 0.049443 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051992 | 0.051992 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.050842 | 0.050842 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.042904 | 0.042904 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.028412 | 0.028412 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.012379 | 0.012379 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 2.8765 | 0.00 | 371.46 | 0.00 | 156.93 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.007454 | 0.007454 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 2.8765 | 0.00 | 413.38 | 0.00 | 155.05 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.007454 | 0.007454 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 2.8440 | 0.00 | 364.56 | 0.00 | 145.63 | 0 | 2 | 1.28 | 0.000013 | 0.000013 | 0.006193 | 0.006193 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 2.8440 | 2.8440 | 654.11 | 375.67 | 143.65 | 143.65 | 0 | 2 | 1.28 | 0.000013 | 0.000013 | 0.006193 | 0.006193 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 2.8328 | 0.00 | 326.17 | 0.00 | 141.08 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005895 | 0.005895 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 2.8290 | 0.00 | 341.97 | 0.00 | 138.86 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.005722 | 0.005722 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 2.8290 | 0.00 | 337.31 | 0.00 | 136.80 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005722 | 0.005722 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 2.8912 | 0.00 | 335.42 | 0.00 | 135.51 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.004450 | 0.004450 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 2.8592 | 0.00 | 319.23 | 0.00 | 131.83 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.003938 | 0.003938 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.5700 | 2.6778 | 418.05 | 206.64 | 105.99 | 110.43 | 0 | 2 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002530 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 2.7463 | 0.00 | 197.98 | 0.00 | 113.26 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.002774 | 0.002774 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.009908 | 0.009908 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.5700 | 2.6778 | 417.43 | 241.54 | 103.75 | 108.11 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002530 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 2.7463 | 0.00 | 215.09 | 0.00 | 110.87 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.002774 | 0.002774 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 3.0601 | 3.0601 | 614.94 | 614.94 | 123.54 | 123.54 | 2 | 0 | 1.28 | 0.000013 | 0.000013 | 0.007274 | 0.007274 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 2.5700 | 2.6129 | 395.96 | 192.30 | 101.47 | 103.17 | 0 | 2 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.001896 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 2.7543 | 2.7543 | 504.99 | 220.72 | 108.75 | 108.75 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.002845 | 0.002845 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 3.2242 | 3.2242 | 705.33 | 705.33 | 127.30 | 127.30 | 2 | 0 | 1.28 | 0.000013 | 0.000013 | 0.010348 | 0.010348 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 2.6396 | 0.00 | 193.21 | 0.00 | 101.82 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002080 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 2.5809 | 0.00 | 185.69 | 0.00 | 99.56 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.001594 | 0.001594 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.010453 | 0.010453 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 2.5809 | 0.00 | 151.80 | 0.00 | 97.16 | 0 | 2 | 1.28 | 0.000013 | 0.000013 | 0.001485 | 0.001485 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011186 | 0.011186 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 2.5700 | 0.00 | 174.07 | 0.00 | 94.30 | 0 | 5 | 1.28 | 0.000013 | 0.000013 | 0.001208 | 0.001208 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.009230 | 0.009230 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 2.5700 | 0.00 | 164.74 | 0.00 | 91.79 | 0 | 4 | 1.28 | 0.000013 | 0.000013 | 0.001208 | 0.001208 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 2.5700 | 0.00 | 132.88 | 0.00 | 89.20 | 0 | 39 | 1.28 | 0.000013 | 0.000013 | 0.001102 | 0.001102 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 3.0543 | 3.0543 | 514.83 | 514.83 | 106.01 | 106.01 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006557 | 0.006557 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 2.5700 | 2.5700 | 289.71 | 120.71 | 86.54 | 86.54 | 8 | 34 | 1.28 | 0.000013 | 0.000013 | 0.000950 | 0.000950 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 3.0543 | 3.0543 | 545.03 | 545.03 | 102.84 | 102.84 | 9 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006735 | 0.006735 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 2.5700 | 2.5700 | 275.47 | 137.21 | 83.79 | 83.79 | 0 | 1 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.001088 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 2.5700 | 2.5700 | 283.35 | 121.99 | 83.79 | 83.79 | 2 | 13 | 1.28 | 0.000013 | 0.000013 | 0.000950 | 0.000950 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 3.0141 | 3.0141 | 503.07 | 503.07 | 98.27 | 98.27 | 11 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005889 | 0.005889 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 2.5700 | 2.5700 | 254.50 | 113.98 | 80.95 | 80.95 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.001063 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 2.5700 | 2.5700 | 283.68 | 99.62 | 80.95 | 80.95 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000302 | 0.000302 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 2.9656 | 2.9656 | 446.10 | 446.10 | 93.41 | 93.41 | 30 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005151 | 0.005151 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 2.5700 | 2.5700 | 233.87 | 109.78 | 78.00 | 78.00 | 0 | 1 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000603 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 2.5700 | 2.5700 | 242.48 | 101.84 | 78.00 | 78.00 | 14 | 36 | 1.28 | 0.000013 | 0.000013 | 0.000300 | 0.000300 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 2.9656 | 2.9656 | 435.22 | 435.22 | 90.01 | 90.01 | 8 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005010 | 0.005010 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 2.5700 | 2.5700 | 225.76 | 95.64 | 74.94 | 74.94 | 12 | 43 | 1.28 | 0.000013 | 0.000013 | 0.000164 | 0.000164 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 2.5700 | 2.5700 | 203.50 | 203.50 | 74.94 | 74.94 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000305 | 0.000305 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 2.8521 | 2.8521 | 382.92 | 382.92 | 83.17 | 83.17 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.003446 | 0.003446 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5700 | 2.5700 | 211.56 | 109.12 | 71.75 | 71.75 | 1 | 2 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000109 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 2.5700 | 2.5700 | 211.01 | 93.69 | 71.75 | 71.75 | 1 | 8 | 1.28 | 0.000013 | 0.000013 | 0.000164 | 0.000164 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 2.5700 | 2.5700 | 124.94 | 124.94 | 71.75 | 71.75 | 3 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000300 | 0.000300 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 2.5700 | 190.61 | 107.22 | 68.41 | 68.41 | 4 | 8 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000101 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 2.5700 | 2.5700 | 187.28 | 99.31 | 68.41 | 68.41 | 1 | 3 | 1.28 | 0.000013 | 0.000013 | 0.000187 | 0.000187 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 2.5700 | 2.5700 | 188.62 | 188.62 | 68.41 | 68.41 | 6 | 6 | 1.28 | 0.000013 | 0.000013 | 0.000295 | 0.000295 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 2.7855 | 2.7855 | 286.16 | 286.16 | 74.15 | 74.15 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002682 | 0.002682 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 2.5700 | 179.39 | 112.18 | 64.90 | 64.90 | 0 | 1 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000087 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 2.5700 | 2.5700 | 170.45 | 81.21 | 64.90 | 64.90 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.000137 | 0.000137 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 2.5700 | 2.5700 | 147.56 | 147.56 | 64.90 | 64.90 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000128 | 0.000128 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 2.5700 | 150.54 | 82.46 | 61.19 | 61.19 | 1 | 5 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000070 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 2.5700 | 2.5700 | 150.71 | 76.43 | 61.19 | 61.19 | 5 | 19 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 2.5700 | 2.5700 | 135.65 | 135.65 | 61.19 | 61.19 | 2 | 7 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 2.5700 | 2.5700 | 140.16 | 73.82 | 57.24 | 57.24 | 1 | 2 | 1.64 | 0.000013 | 0.000013 | 0.000042 | 0.000042 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 2.5700 | 2.5700 | 142.08 | 72.89 | 57.24 | 57.24 | 6 | 13 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 2.5700 | 2.5700 | 80.62 | 80.62 | 57.24 | 57.24 | 5 | 11 | 1.28 | 0.000013 | 0.000013 | 0.000075 | 0.000075 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 2.5700 | 2.5700 | 129.50 | 129.50 | 57.24 | 57.24 | 7 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000462 | 0.000462 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 2.5700 | 2.5700 | 108.44 | 59.36 | 52.99 | 52.99 | 0 | 7 | 1.64 | 0.000013 | 0.000013 | 0.000010 | 0.000010 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 2.5700 | 2.5700 | 126.20 | 55.03 | 52.99 | 52.99 | 2 | 11 | 1.28 | 0.000013 | 0.000013 | 0.000032 | 0.000032 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 2.5700 | 2.5700 | 114.97 | 114.97 | 52.99 | 52.99 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000022 | 0.000022 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 2.5700 | 2.5700 | 121.53 | 60.54 | 52.99 | 52.99 | 2 | 5 | 1.28 | 0.000013 | 0.000013 | 0.000426 | 0.000426 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 2.5700 | 2.5700 | 85.42 | 47.64 | 48.38 | 48.38 | 1 | 1 | 1.64 | 0.000013 | 0.000013 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 2.5700 | 2.5700 | 79.75 | 59.05 | 48.38 | 48.38 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000006 | 0.000006 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 2.5700 | 2.5700 | 76.81 | 76.81 | 48.38 | 48.38 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000006 | 0.000006 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 2.5700 | 2.5700 | 90.73 | 54.51 | 48.38 | 48.38 | 2 | 2 | 1.28 | 0.000013 | 0.000013 | 0.000094 | 0.000094 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 2.5700 | 2.5700 | 74.98 | 42.44 | 43.27 | 43.27 | 9 | 4 | 1.64 | 0.000013 | 0.000013 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 2.5700 | 2.5700 | 65.16 | 43.17 | 43.27 | 43.27 | 10 | 2 | 1.28 | 0.000013 | 0.000013 | 0.000001 | 0.000001 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 2.5700 | 2.5700 | 81.32 | 81.32 | 43.27 | 43.27 | 2 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000012 | 0.000012 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 2.5700 | 2.5700 | 49.52 | 33.01 | 37.47 | 37.47 | 0 | 1 | 1.64 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 2.5700 | 2.5700 | 48.89 | 48.89 | 37.47 | 37.47 | 1 | 1 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 2.5700 | 2.5700 | 20.15 | 20.15 | 30.60 | 30.60 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 2.5700 | 2.5700 | 26.84 | 26.84 | 21.63 | 21.63 | 3 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 3.2827 | 3.2827 | 348.43 | 348.43 | 96.84 | 96.84 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.007896 | 0.007896 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 3.0989 | 3.0989 | 275.94 | 275.94 | 85.47 | 85.47 | 5 | 0 | 1.28 | 0.000002 | 0.000002 | 0.005259 | 0.005259 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 3.1338 | 3.1338 | 261.38 | 261.38 | 82.86 | 82.86 | 19 | 0 | 1.28 | 0.000002 | 0.000002 | 0.005365 | 0.005365 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 3.0659 | 3.0659 | 219.55 | 219.55 | 76.99 | 76.99 | 11 | 0 | 1.28 | 0.000002 | 0.000002 | 0.004619 | 0.004619 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 2.6414 | 2.6414 | 128.65 | 128.65 | 58.93 | 58.93 | 11 | 0 | 1.28 | 0.000002 | 0.000002 | 0.001598 | 0.001598 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 2.5700 | 2.5700 | 101.43 | 101.43 | 52.33 | 52.33 | 2 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000765 | 0.000765 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 2.5700 | 2.5700 | 54.82 | 54.82 | 38.47 | 38.47 | 3 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000111 | 0.000111 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 2.5700 | 2.5700 | 24.45 | 24.45 | 25.69 | 25.69 | 1 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000001 | 0.000001 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.5700 | 2.5700 | 12.69 | 12.69 | 18.51 | 18.51 | 1 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] $PA = (BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.3860 | 0.00 | 514.69 | 0.00 | 184.72 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.049977 | 0.049977 | 0.000000 | 0.007050 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.3860 | 0.00 | 572.78 | 0.00 | 182.51 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.049977 | 0.049977 | 0.000000 | 0.005789 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.3622 | 0.00 | 509.51 | 0.00 | 172.16 | 0 | 2 | 1.28 | 0.000044 | 0.000044 | 0.046166 | 0.046166 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 3.3622 | 3.3622 | 914.18 | 525.04 | 169.82 | 169.82 | 0 | 2 | 1.28 | 0.000044 | 0.000044 | 0.046166 | 0.046166 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 3.3567 | 0.00 | 457.97 | 0.00 | 167.17 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.045869 | 0.045869 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.3549 | 0.00 | 480.92 | 0.00 | 164.67 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.045161 | 0.045161 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.3549 | 0.00 | 474.37 | 0.00 | 162.23 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.045161 | 0.045161 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 3.7935 | 0.00 | 577.44 | 0.00 | 177.80 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.044565 | 0.044565 | 0.000000 | 0.002999 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 3.7639 | 0.00 | 553.20 | 0.00 | 173.54 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.042274 | 0.042274 | 0.000000 | 0.000346 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.5700 | 3.4123 | 418.05 | 335.55 | 105.99 | 140.72 | 0 | 2 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.039720 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 3.7087 | 0.00 | 361.05 | 0.00 | 152.94 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.039908 | 0.039908 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.050313 | 0.050313 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.5700 | 3.4123 | 417.43 | 392.22 | 103.75 | 137.76 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.039720 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 3.7087 | 0.00 | 392.24 | 0.00 | 149.72 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.039908 | 0.039908 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 3.8748 | 3.8748 | 985.93 | 985.93 | 156.43 | 156.43 | 2 | 0 | 1.28 | 0.000044 | 0.000044 | 0.048737 | 0.048737 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 2.5700 | 3.3806 | 395.96 | 321.89 | 101.47 | 133.48 | 0 | 2 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.037704 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 3.7126 | 3.7126 | 917.52 | 401.02 | 146.59 | 146.59 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.040083 | 0.040083 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 3.9424 | 3.9424 | 1054.55 | 1054.55 | 155.66 | 155.66 | 2 | 0 | 1.28 | 0.000044 | 0.000044 | 0.047508 | 0.047508 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.3936 | 0.00 | 319.36 | 0.00 | 130.91 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.037502 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 3.6277 | 0.00 | 366.88 | 0.00 | 139.94 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.036099 | 0.036099 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.047541 | 0.047541 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 3.6277 | 0.00 | 299.93 | 0.00 | 136.57 | 0 | 2 | 1.28 | 0.000044 | 0.000044 | 0.033629 | 0.033629 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.049568 | 0.049568 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 3.5991 | 0.00 | 341.40 | 0.00 | 132.06 | 0 | 5 | 1.28 | 0.000044 | 0.000044 | 0.032317 | 0.032317 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.048837 | 0.048837 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 3.5991 | 0.00 | 323.10 | 0.00 | 128.54 | 0 | 4 | 1.28 | 0.000044 | 0.000044 | 0.032317 | 0.032317 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 3.5991 | 0.00 | 260.61 | 0.00 | 124.92 | 0 | 39 | 1.28 | 0.000044 | 0.000044 | 0.029471 | 0.029471 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 3.8593 | 3.8593 | 821.97 | 821.97 | 133.95 | 133.95 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.043780 | 0.043780 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 3.5792 | 3.5792 | 561.90 | 234.11 | 120.52 | 120.52 | 8 | 34 | 1.28 | 0.000044 | 0.000044 | 0.028624 | 0.028624 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 3.8593 | 3.8593 | 870.19 | 870.19 | 129.95 | 129.95 | 9 | 0 | 1.28 | 0.000044 | 0.000044 | 0.045019 | 0.045019 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 2.5700 | 3.5942 | 275.47 | 268.37 | 83.79 | 117.18 | 0 | 1 | 1.64 | 0.000024 | 0.000044 | 0.000003 | 0.029969 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 3.5792 | 3.5792 | 549.57 | 236.60 | 116.69 | 116.69 | 2 | 13 | 1.28 | 0.000044 | 0.000044 | 0.028624 | 0.028624 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 3.8396 | 3.8396 | 816.38 | 816.38 | 125.18 | 125.18 | 11 | 0 | 1.28 | 0.000044 | 0.000044 | 0.043203 | 0.043203 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 2.5700 | 3.5942 | 254.50 | 222.93 | 80.95 | 113.21 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.000002 | 0.029263 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 3.4277 | 3.4277 | 504.61 | 177.21 | 107.96 | 107.96 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.023684 | 0.023684 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 3.8159 | 3.8159 | 738.61 | 738.61 | 120.19 | 120.19 | 30 | 0 | 1.28 | 0.000044 | 0.000044 | 0.042440 | 0.042440 | 1.000000 | 1.000000 | 0.0100 | 0.000001 | 0.000000 | 0.000001 |
| 37 | Ship | Tanker | 65,000 | 2.5700 | 3.5200 | 233.87 | 205.95 | 78.00 | 106.84 | 0 | 1 | 1.64 | 0.000024 | 0.000044 | 0.000002 | 0.026103 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 3.4343 | 3.4343 | 433.00 | 181.86 | 104.24 | 104.24 | 14 | 36 | 1.28 | 0.000044 | 0.000044 | 0.022509 | 0.022509 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 3.8159 | 3.8159 | 720.59 | 720.59 | 115.82 | 115.82 | 8 | 0 | 1.28 | 0.000044 | 0.000044 | 0.041238 | 0.041238 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 3.3645 | 3.3645 | 386.93 | 163.91 | 98.11 | 98.11 | 12 | 43 | 1.28 | 0.000044 | 0.000044 | 0.019714 | 0.019714 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 3.4343 | 3.4343 | 363.39 | 363.39 | 100.15 | 100.15 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.022874 | 0.022874 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 3.7604 | 3.7604 | 665.66 | 665.66 | 109.66 | 109.66 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.037547 | 0.037547 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5700 | 3.3186 | 211.56 | 181.95 | 71.75 | 92.65 | 1 | 2 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017968 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 3.1661 | 3.1661 | 320.25 | 142.20 | 88.39 | 88.39 | 1 | 8 | 1.28 | 0.000044 | 0.000044 | 0.019714 | 0.019714 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 3.4343 | 3.4343 | 223.10 | 223.10 | 95.88 | 95.88 | 3 | 0 | 1.28 | 0.000044 | 0.000044 | 0.022509 | 0.022509 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 3.3106 | 190.61 | 177.92 | 68.41 | 88.13 | 4 | 8 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017673 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 3.1770 | 3.1770 | 286.20 | 151.77 | 84.57 | 84.57 | 1 | 3 | 1.28 | 0.000044 | 0.000044 | 0.020286 | 0.020286 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 3.4343 | 3.4343 | 336.82 | 336.82 | 91.42 | 91.42 | 6 | 6 | 1.28 | 0.000044 | 0.000044 | 0.022144 | 0.022144 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 3.7278 | 3.7278 | 512.53 | 512.53 | 99.23 | 99.23 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.034653 | 0.034653 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 3.2943 | 179.39 | 184.32 | 64.90 | 83.19 | 0 | 1 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017081 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 3.1549 | 3.1549 | 256.86 | 122.38 | 79.67 | 79.67 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.018201 | 0.018201 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 3.3420 | 3.3420 | 249.52 | 249.52 | 84.40 | 84.40 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.017924 | 0.017924 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 3.2777 | 150.54 | 134.12 | 61.19 | 78.04 | 1 | 5 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.015406 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 3.1072 | 3.1072 | 220.31 | 111.72 | 73.98 | 73.98 | 5 | 19 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 3.2861 | 3.2861 | 221.78 | 221.78 | 78.24 | 78.24 | 2 | 7 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 3.2251 | 3.2251 | 220.72 | 116.26 | 71.83 | 71.83 | 1 | 2 | 1.64 | 0.000044 | 0.000044 | 0.013483 | 0.013483 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 3.1072 | 3.1072 | 207.68 | 106.55 | 69.20 | 69.20 | 6 | 13 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.2861 | 3.2861 | 131.81 | 131.81 | 73.19 | 73.19 | 5 | 11 | 1.28 | 0.000044 | 0.000044 | 0.015685 | 0.015685 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 3.4908 | 3.4908 | 238.92 | 238.92 | 77.75 | 77.75 | 7 | 0 | 1.28 | 0.000044 | 0.000044 | 0.024064 | 0.024064 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 3.0850 | 3.0850 | 156.25 | 85.54 | 63.61 | 63.61 | 0 | 7 | 1.64 | 0.000044 | 0.000044 | 0.009669 | 0.009669 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 3.0406 | 3.0406 | 176.65 | 77.03 | 62.70 | 62.70 | 2 | 11 | 1.28 | 0.000044 | 0.000044 | 0.012655 | 0.012655 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 3.1584 | 3.1584 | 173.64 | 173.64 | 65.12 | 65.12 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.011557 | 0.011557 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 3.4968 | 3.4968 | 224.98 | 112.08 | 72.10 | 72.10 | 2 | 5 | 1.28 | 0.000044 | 0.000044 | 0.021316 | 0.021316 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 2.9272 | 2.9272 | 110.82 | 61.81 | 55.10 | 55.10 | 1 | 1 | 1.64 | 0.000044 | 0.000044 | 0.006050 | 0.006050 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 2.9135 | 2.9135 | 102.50 | 75.90 | 54.84 | 54.84 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.008214 | 0.008214 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.0279 | 3.0279 | 106.61 | 106.61 | 56.99 | 56.99 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.008214 | 0.008214 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.3186 | 3.3186 | 151.28 | 90.89 | 62.47 | 62.47 | 2 | 2 | 1.28 | 0.000044 | 0.000044 | 0.015626 | 0.015626 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 2.9138 | 2.9138 | 96.38 | 54.56 | 49.06 | 49.06 | 9 | 4 | 1.64 | 0.000044 | 0.000044 | 0.005830 | 0.005830 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 2.8176 | 2.8176 | 78.32 | 51.89 | 47.44 | 47.44 | 10 | 2 | 1.28 | 0.000044 | 0.000044 | 0.005504 | 0.005504 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.1067 | 3.1067 | 118.83 | 118.83 | 52.30 | 52.30 | 2 | 0 | 1.28 | 0.000044 | 0.000044 | 0.009835 | 0.009835 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 2.6286 | 2.6286 | 51.80 | 34.53 | 38.33 | 38.33 | 0 | 1 | 1.64 | 0.000044 | 0.000044 | 0.002314 | 0.002314 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 2.8131 | 2.8131 | 58.58 | 58.58 | 41.02 | 41.02 | 1 | 1 | 1.28 | 0.000044 | 0.000044 | 0.004128 | 0.004128 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 2.5700 | 2.5700 | 20.15 | 20.15 | 30.60 | 30.60 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.001174 | 0.001174 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 2.5700 | 2.5700 | 26.84 | 26.84 | 21.63 | 21.63 | 3 | 0 | 1.28 | 0.000044 | 0.000044 | 0.001195 | 0.001195 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.2229 | 4.2229 | 576.59 | 576.59 | 124.58 | 124.58 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.042850 | 0.042850 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.1439 | 4.1439 | 493.44 | 493.44 | 114.30 | 114.30 | 5 | 0 | 1.28 | 0.000007 | 0.000007 | 0.040455 | 0.040455 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.1610 | 4.1610 | 460.81 | 460.81 | 110.02 | 110.02 | 19 | 0 | 1.28 | 0.000007 | 0.000007 | 0.038529 | 0.038529 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.1278 | 4.1278 | 397.98 | 397.98 | 103.65 | 103.65 | 11 | 0 | 1.28 | 0.000007 | 0.000007 | 0.037773 | 0.037773 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 3.9202 | 3.9202 | 283.35 | 283.35 | 87.46 | 87.46 | 11 | 0 | 1.28 | 0.000007 | 0.000007 | 0.031709 | 0.031709 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 3.7986 | 3.7986 | 221.58 | 221.58 | 77.34 | 77.34 | 2 | 0 | 1.28 | 0.000007 | 0.000007 | 0.026981 | 0.026981 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3.5251 | 3.5251 | 103.14 | 103.14 | 52.77 | 52.77 | 3 | 0 | 1.28 | 0.000007 | 0.000007 | 0.016380 | 0.016380 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 2.9492 | 2.9492 | 32.19 | 32.19 | 29.48 | 29.48 | 1 | 0 | 1.28 | 0.000007 | 0.000007 | 0.004607 | 0.004607 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.5700 | 2.5700 | 12.69 | 12.69 | 18.51 | 18.51 | 1 | 0 | 1.28 | 0.000007 | 0.000007 | 0.000293 | 0.000293 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000002** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] $PA = (BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.5148 | 0.00 | 554.61 | 0.00 | 191.75 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065848 | 0.065848 | 0.000000 | 0.010865 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.5148 | 0.00 | 617.20 | 0.00 | 189.45 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.065848 | 0.065848 | 0.000000 | 0.009650 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.4933 | 0.00 | 550.00 | 0.00 | 178.87 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.061753 | 0.061753 | 0.000000 | 0.003647 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 3.4933 | 3.4933 | 986.84 | 566.76 | 176.44 | 176.44 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.061753 | 0.061753 | 0.002164 | 0.002164 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 3.4892 | 0.00 | 494.85 | 0.00 | 173.77 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.061766 | 0.061766 | 0.000000 | 0.000491 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.4879 | 0.00 | 519.81 | 0.00 | 171.20 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.060928 | 0.060928 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.4879 | 0.00 | 512.72 | 0.00 | 168.66 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060928 | 0.060928 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.0217 | 0.00 | 649.00 | 0.00 | 188.49 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062435 | 0.062435 | 0.000000 | 0.009133 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 3.9927 | 0.00 | 622.50 | 0.00 | 184.09 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.059812 | 0.059812 | 0.000000 | 0.006693 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.5700 | 3.5981 | 418.05 | 373.08 | 105.99 | 148.38 | 0 | 2 | 10.20 | 0.000013 | 0.000024 | 0.000444 | 0.059645 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 3.9520 | 0.00 | 409.99 | 0.00 | 162.98 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.059101 | 0.059101 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.063449 | 0.063449 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.5700 | 3.5981 | 417.43 | 436.09 | 103.75 | 145.26 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.000444 | 0.059645 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 3.9520 | 0.00 | 445.41 | 0.00 | 159.55 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.059101 | 0.059101 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 4.0808 | 4.0808 | 1093.57 | 1093.57 | 164.75 | 164.75 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064173 | 0.064173 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 2.5700 | 3.5747 | 395.96 | 359.93 | 101.47 | 141.14 | 0 | 2 | 10.20 | 0.000013 | 0.000024 | 0.000403 | 0.058743 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 3.9549 | 3.9549 | 1041.22 | 455.09 | 156.15 | 156.15 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.059164 | 0.059164 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 4.1240 | 4.1240 | 1153.97 | 1153.97 | 162.83 | 162.83 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058892 | 0.058892 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.5843 | 0.00 | 356.27 | 0.00 | 138.27 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.000399 | 0.057505 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 3.8925 | 0.00 | 422.39 | 0.00 | 150.16 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057374 | 0.057374 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058846 | 0.058846 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 3.8925 | 0.00 | 345.31 | 0.00 | 146.54 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.053353 | 0.053353 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.061163 | 0.061163 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 3.8715 | 0.00 | 395.02 | 0.00 | 142.06 | 0 | 5 | 1.28 | 0.000024 | 0.000024 | 0.052626 | 0.052626 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.061949 | 0.061949 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 3.8715 | 0.00 | 373.85 | 0.00 | 138.27 | 0 | 4 | 1.28 | 0.000024 | 0.000024 | 0.052626 | 0.052626 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 3.8715 | 0.00 | 301.53 | 0.00 | 134.37 | 0 | 39 | 1.28 | 0.000024 | 0.000024 | 0.047868 | 0.047868 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 4.0629 | 4.0629 | 910.98 | 910.98 | 141.01 | 141.01 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057474 | 0.057474 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 3.8568 | 3.8568 | 652.44 | 271.84 | 129.86 | 129.86 | 8 | 34 | 1.28 | 0.000024 | 0.000024 | 0.047365 | 0.047365 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 4.0629 | 4.0629 | 964.42 | 964.42 | 136.80 | 136.80 | 9 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059149 | 0.059149 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 2.5700 | 3.8678 | 275.47 | 310.79 | 83.79 | 126.10 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.000269 | 0.048933 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 3.8568 | 3.8568 | 638.12 | 274.73 | 125.74 | 125.74 | 2 | 13 | 1.28 | 0.000024 | 0.000024 | 0.047365 | 0.047365 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 4.0484 | 4.0484 | 907.58 | 907.58 | 131.99 | 131.99 | 11 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057553 | 0.057553 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 2.5700 | 3.8678 | 254.50 | 258.16 | 80.95 | 121.83 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000259 | 0.047747 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 3.7453 | 3.7453 | 602.47 | 211.58 | 117.97 | 117.97 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045552 | 0.045552 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 4.0309 | 4.0309 | 824.21 | 824.21 | 126.96 | 126.96 | 30 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057567 | 0.057567 | 1.000000 | 1.000000 | 0.0200 | 0.000001 | 0.000000 | 0.000001 |
| 37 | Ship | Tanker | 65,000 | 2.5700 | 3.8132 | 233.87 | 241.69 | 78.00 | 115.74 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.000216 | 0.045704 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 3.7502 | 3.7502 | 516.31 | 216.85 | 113.82 | 113.82 | 14 | 36 | 1.28 | 0.000024 | 0.000024 | 0.042936 | 0.042936 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 4.0309 | 4.0309 | 804.10 | 804.10 | 122.34 | 122.34 | 8 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055888 | 0.055888 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 3.6988 | 3.6988 | 467.64 | 198.10 | 107.86 | 107.86 | 12 | 43 | 1.28 | 0.000024 | 0.000024 | 0.040452 | 0.040452 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 3.7502 | 3.7502 | 433.31 | 433.31 | 109.36 | 109.36 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043650 | 0.043650 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 3.9901 | 3.9901 | 749.48 | 749.48 | 116.35 | 116.35 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053096 | 0.053096 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5700 | 3.6650 | 211.56 | 221.93 | 71.75 | 102.32 | 1 | 2 | 1.64 | 0.000013 | 0.000024 | 0.000132 | 0.038742 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 3.4169 | 3.4169 | 373.00 | 165.62 | 95.40 | 95.40 | 1 | 8 | 1.28 | 0.000024 | 0.000024 | 0.040452 | 0.040452 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 3.7502 | 3.7502 | 266.03 | 266.03 | 104.70 | 104.70 | 3 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042936 | 0.042936 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 3.6591 | 190.61 | 217.35 | 68.41 | 97.41 | 4 | 8 | 1.64 | 0.000013 | 0.000024 | 0.000129 | 0.038441 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 3.4250 | 3.4250 | 332.61 | 176.38 | 91.17 | 91.17 | 1 | 3 | 1.28 | 0.000024 | 0.000024 | 0.040985 | 0.040985 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 3.7502 | 3.7502 | 401.62 | 401.62 | 99.83 | 99.83 | 6 | 6 | 1.28 | 0.000024 | 0.000024 | 0.042222 | 0.042222 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 3.9661 | 3.9661 | 580.15 | 580.15 | 105.58 | 105.58 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.050259 | 0.050259 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 3.6472 | 179.39 | 225.92 | 64.90 | 92.11 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.000124 | 0.037823 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 3.4087 | 3.4087 | 299.84 | 142.86 | 86.08 | 86.08 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.037904 | 0.037904 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 3.6822 | 3.6822 | 302.91 | 302.91 | 92.99 | 92.99 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.037635 | 0.037635 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 3.6349 | 150.54 | 164.95 | 61.19 | 86.55 | 1 | 5 | 1.64 | 0.000013 | 0.000024 | 0.000106 | 0.034699 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 3.3736 | 3.3736 | 259.70 | 131.69 | 80.32 | 80.32 | 5 | 19 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 3.6411 | 3.6411 | 272.29 | 272.29 | 86.69 | 86.69 | 2 | 7 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 3.5962 | 3.5962 | 274.44 | 144.56 | 80.09 | 80.09 | 1 | 2 | 1.64 | 0.000024 | 0.000024 | 0.032215 | 0.032215 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 3.3736 | 3.3736 | 244.82 | 125.60 | 75.14 | 75.14 | 6 | 13 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.6411 | 3.6411 | 161.83 | 161.83 | 81.09 | 81.09 | 5 | 11 | 1.28 | 0.000024 | 0.000024 | 0.034999 | 0.034999 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 3.7918 | 3.7918 | 281.89 | 281.89 | 84.45 | 84.45 | 7 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043318 | 0.043318 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 3.4931 | 3.4931 | 200.33 | 109.67 | 72.03 | 72.03 | 0 | 7 | 1.64 | 0.000024 | 0.000024 | 0.027260 | 0.027260 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 3.3246 | 3.3246 | 211.19 | 92.09 | 68.55 | 68.55 | 2 | 11 | 1.28 | 0.000024 | 0.000024 | 0.031223 | 0.031223 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 3.5471 | 3.5471 | 219.01 | 219.01 | 73.14 | 73.14 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.029841 | 0.029841 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 3.7961 | 3.7961 | 265.15 | 132.10 | 78.28 | 78.28 | 2 | 5 | 1.28 | 0.000024 | 0.000024 | 0.037981 | 0.037981 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.3771 | 3.3771 | 147.50 | 82.27 | 63.57 | 63.57 | 1 | 1 | 1.64 | 0.000024 | 0.000024 | 0.020767 | 0.020767 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 3.2311 | 3.2311 | 126.06 | 93.34 | 60.82 | 60.82 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.024832 | 0.024832 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.4511 | 3.4511 | 138.50 | 138.50 | 64.96 | 64.96 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.024832 | 0.024832 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.6650 | 3.6650 | 184.51 | 110.86 | 68.99 | 68.99 | 2 | 2 | 1.28 | 0.000024 | 0.000024 | 0.033574 | 0.033574 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.3671 | 3.3671 | 128.70 | 72.86 | 56.69 | 56.69 | 9 | 4 | 1.64 | 0.000024 | 0.000024 | 0.020363 | 0.020363 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.1605 | 3.1605 | 98.54 | 65.29 | 53.21 | 53.21 | 10 | 2 | 1.28 | 0.000024 | 0.000024 | 0.019567 | 0.019567 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.5091 | 3.5091 | 151.60 | 151.60 | 59.08 | 59.08 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.026989 | 0.026989 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.1573 | 3.1573 | 74.73 | 49.82 | 46.03 | 46.03 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.011894 | 0.011894 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.2931 | 3.2931 | 80.27 | 80.27 | 48.01 | 48.01 | 1 | 1 | 1.28 | 0.000024 | 0.000024 | 0.016457 | 0.016457 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.0239 | 3.0239 | 27.89 | 27.89 | 36.00 | 36.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.007843 | 0.007843 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.0076 | 3.0076 | 36.76 | 36.76 | 25.32 | 25.32 | 3 | 0 | 1.28 | 0.000024 | 0.000024 | 0.008244 | 0.008244 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.4607 | 4.4607 | 643.35 | 643.35 | 131.60 | 131.60 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.054402 | 0.054402 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.4082 | 4.4082 | 558.39 | 558.39 | 121.59 | 121.59 | 5 | 0 | 1.28 | 0.000004 | 0.000004 | 0.054213 | 0.054213 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.4208 | 4.4208 | 520.15 | 520.15 | 116.89 | 116.89 | 19 | 0 | 1.28 | 0.000004 | 0.000004 | 0.051002 | 0.051002 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.3964 | 4.3964 | 451.45 | 451.45 | 110.39 | 110.39 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.051022 | 0.051022 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.2436 | 4.2436 | 332.03 | 332.03 | 94.67 | 94.67 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.049171 | 0.049171 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.1541 | 4.1541 | 265.00 | 265.00 | 84.58 | 84.58 | 2 | 0 | 1.28 | 0.000004 | 0.000004 | 0.045734 | 0.045734 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3.9529 | 3.9529 | 129.69 | 129.69 | 59.17 | 59.17 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.034611 | 0.034611 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.5291 | 3.5291 | 46.10 | 46.10 | 35.28 | 35.28 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.016931 | 0.016931 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.7802 | 2.7802 | 14.85 | 14.85 | 20.02 | 20.02 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.003564 | 0.003564 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000004** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.6365 | 0.00 | 593.66 | 0.00 | 198.39 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076995 | 0.076995 | 0.000000 | 0.014218 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.6365 | 0.00 | 660.65 | 0.00 | 196.01 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.076995 | 0.076995 | 0.000000 | 0.013043 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.6170 | 0.00 | 589.64 | 0.00 | 185.20 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.072779 | 0.072779 | 0.000000 | 0.007322 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 3.6170 | 3.6170 | 1057.96 | 607.61 | 182.68 | 182.68 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.072779 | 0.072779 | 0.005890 | 0.005890 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 3.6143 | 0.00 | 530.95 | 0.00 | 180.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.073140 | 0.073140 | 0.000000 | 0.004318 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.6134 | 0.00 | 557.90 | 0.00 | 177.36 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.072200 | 0.072200 | 0.000000 | 0.002732 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.6134 | 0.00 | 550.29 | 0.00 | 174.73 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072200 | 0.072200 | 0.000000 | 0.001102 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2371 | 0.00 | 720.37 | 0.00 | 198.59 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076095 | 0.076095 | 0.000000 | 0.014317 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.2086 | 0.00 | 691.66 | 0.00 | 194.05 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.073275 | 0.073275 | 0.000000 | 0.012051 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.6796 | 3.7734 | 454.47 | 410.32 | 110.51 | 155.61 | 0 | 2 | 10.20 | 0.000013 | 0.000024 | 0.009723 | 0.076286 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1818 | 0.00 | 459.04 | 0.00 | 172.45 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.074796 | 0.074796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.071830 | 0.071830 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.6796 | 3.7734 | 453.80 | 479.62 | 108.18 | 152.34 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.009723 | 0.076286 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1818 | 0.00 | 498.70 | 0.00 | 168.82 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.074796 | 0.074796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 4.2752 | 4.2752 | 1200.28 | 1200.28 | 172.60 | 172.60 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074919 | 0.074919 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 2.6695 | 3.7580 | 427.23 | 397.78 | 105.40 | 148.38 | 0 | 2 | 10.20 | 0.000013 | 0.000024 | 0.009269 | 0.077133 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 4.1837 | 4.1837 | 1165.15 | 509.26 | 165.19 | 165.19 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.074701 | 0.074701 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 4.2955 | 4.2955 | 1251.90 | 1251.90 | 169.60 | 169.60 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065658 | 0.065658 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.7643 | 0.00 | 392.95 | 0.00 | 145.21 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.009073 | 0.074555 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 4.1424 | 0.00 | 478.36 | 0.00 | 159.80 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076360 | 0.076360 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065539 | 0.065539 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 4.1424 | 0.00 | 391.07 | 0.00 | 155.95 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.070669 | 0.070669 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068095 | 0.068095 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 4.1285 | 0.00 | 449.20 | 0.00 | 151.49 | 0 | 5 | 1.28 | 0.000024 | 0.000024 | 0.071012 | 0.071012 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.070341 | 0.070341 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 4.1285 | 0.00 | 425.13 | 0.00 | 147.45 | 0 | 4 | 1.28 | 0.000024 | 0.000024 | 0.071012 | 0.071012 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 4.1285 | 0.00 | 342.90 | 0.00 | 143.29 | 0 | 39 | 1.28 | 0.000024 | 0.000024 | 0.064146 | 0.064146 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 4.2550 | 4.2550 | 999.19 | 999.19 | 147.68 | 147.68 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.066612 | 0.066612 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 4.1188 | 4.1188 | 744.09 | 310.03 | 138.69 | 138.69 | 8 | 34 | 1.28 | 0.000024 | 0.000024 | 0.064317 | 0.064317 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 4.2550 | 4.2550 | 1057.81 | 1057.81 | 143.27 | 143.27 | 9 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068689 | 0.068689 | 1.000000 | 1.000000 | 0.0400 | 0.000001 | 0.000000 | 0.000001 |
| 31 | Ship | Tanker | 75,000 | 2.6561 | 4.1261 | 294.23 | 353.67 | 86.60 | 134.52 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.006930 | 0.065910 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 4.1188 | 4.1188 | 727.76 | 313.32 | 134.28 | 134.28 | 2 | 13 | 1.28 | 0.000024 | 0.000024 | 0.064317 | 0.064317 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 4.2455 | 4.2455 | 998.08 | 998.08 | 138.41 | 138.41 | 11 | 0 | 1.28 | 0.000024 | 0.000024 | 0.067403 | 0.067403 | 1.000000 | 1.000000 | 0.0400 | 0.000001 | 0.000000 | 0.000001 |
| 34 | Ship | Tanker | 70,000 | 2.6561 | 4.1261 | 271.83 | 293.79 | 83.66 | 129.96 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.006697 | 0.064192 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 4.0451 | 4.0451 | 702.77 | 246.80 | 127.41 | 127.41 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069100 | 0.069100 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 4.2339 | 4.2339 | 909.30 | 909.30 | 133.36 | 133.36 | 30 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068294 | 0.068294 | 1.000000 | 1.000000 | 0.0400 | 0.000003 | 0.000000 | 0.000003 |
| 37 | Ship | Tanker | 65,000 | 2.6382 | 4.0900 | 246.46 | 278.04 | 80.07 | 124.14 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.006126 | 0.064613 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 4.0483 | 4.0483 | 601.67 | 252.70 | 122.87 | 122.87 | 14 | 36 | 1.28 | 0.000024 | 0.000024 | 0.064521 | 0.064521 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 4.2339 | 4.2339 | 887.12 | 887.12 | 128.51 | 128.51 | 8 | 0 | 1.28 | 0.000024 | 0.000024 | 0.066163 | 0.066163 | 1.000000 | 1.000000 | 0.0400 | 0.000001 | 0.000000 | 0.000001 |
| 40 | Ship | Bulk Carrier | 60,000 | 4.0143 | 4.0143 | 550.83 | 233.34 | 117.06 | 117.06 | 12 | 43 | 1.28 | 0.000024 | 0.000024 | 0.064034 | 0.064034 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 4.0483 | 4.0483 | 504.94 | 504.94 | 118.05 | 118.05 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065674 | 0.065674 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 4.2069 | 4.2069 | 833.14 | 833.14 | 122.68 | 122.68 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064635 | 0.064635 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5893 | 3.9920 | 214.76 | 263.29 | 72.29 | 111.45 | 1 | 2 | 1.64 | 0.000013 | 0.000024 | 0.004785 | 0.063531 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 3.6536 | 3.6536 | 426.47 | 189.36 | 102.01 | 102.01 | 1 | 8 | 1.28 | 0.000024 | 0.000024 | 0.064034 | 0.064034 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.0483 | 4.0483 | 310.00 | 310.00 | 113.02 | 113.02 | 3 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064521 | 0.064521 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5874 | 3.9881 | 193.19 | 258.19 | 68.88 | 106.16 | 4 | 8 | 1.64 | 0.000013 | 0.000024 | 0.004737 | 0.063430 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 3.6590 | 3.6590 | 379.61 | 201.30 | 97.40 | 97.40 | 1 | 3 | 1.28 | 0.000024 | 0.000024 | 0.064165 | 0.064165 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 4.0483 | 4.0483 | 468.02 | 468.02 | 107.76 | 107.76 | 6 | 6 | 1.28 | 0.000024 | 0.000024 | 0.063369 | 0.063369 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000001 |
| 49 | Ship | Container | 50,000 | 4.1911 | 4.1911 | 647.83 | 647.83 | 111.57 | 111.57 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062129 | 0.062129 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5834 | 3.9802 | 181.26 | 269.06 | 65.24 | 100.52 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.004642 | 0.063212 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 3.6482 | 3.6482 | 343.46 | 163.64 | 92.13 | 92.13 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.060458 | 0.060458 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 4.0034 | 4.0034 | 358.06 | 358.06 | 101.10 | 101.10 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060381 | 0.060381 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5793 | 3.9721 | 151.63 | 196.98 | 61.41 | 94.57 | 1 | 5 | 1.64 | 0.000013 | 0.000024 | 0.004117 | 0.058462 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 3.6250 | 3.6250 | 299.84 | 152.05 | 86.31 | 86.31 | 5 | 19 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 3.9762 | 3.9762 | 324.71 | 324.71 | 94.67 | 94.67 | 2 | 7 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000001 | 0.000001 |
| 56 | Ship | Tanker | 35,000 | 3.9465 | 3.9465 | 330.51 | 174.09 | 87.90 | 87.90 | 1 | 2 | 1.64 | 0.000024 | 0.000024 | 0.056546 | 0.056546 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 3.6250 | 3.6250 | 282.67 | 145.01 | 80.74 | 80.74 | 6 | 13 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.9762 | 3.9762 | 192.98 | 192.98 | 88.56 | 88.56 | 5 | 11 | 1.28 | 0.000024 | 0.000024 | 0.058577 | 0.058577 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000001 | 0.000001 |
| 59 | Ship | Container | 35,000 | 4.0758 | 4.0758 | 325.71 | 325.71 | 90.78 | 90.78 | 7 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062339 | 0.062339 | 1.000000 | 1.000000 | 0.0400 | 0.000001 | 0.000000 | 0.000001 |
| 60 | Ship | Tanker | 30,000 | 3.8783 | 3.8783 | 246.96 | 135.19 | 79.97 | 79.97 | 0 | 7 | 1.64 | 0.000024 | 0.000024 | 0.053837 | 0.053837 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 3.5926 | 3.5926 | 246.61 | 107.54 | 74.08 | 74.08 | 2 | 11 | 1.28 | 0.000024 | 0.000024 | 0.056074 | 0.056074 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 3.9141 | 3.9141 | 266.67 | 266.67 | 80.71 | 80.71 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055356 | 0.055356 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 4.0787 | 4.0787 | 306.09 | 152.49 | 84.10 | 84.10 | 2 | 5 | 1.28 | 0.000024 | 0.000024 | 0.053796 | 0.053796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.8016 | 3.8016 | 186.91 | 104.25 | 71.56 | 71.56 | 1 | 1 | 1.64 | 0.000024 | 0.000024 | 0.047021 | 0.047021 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 3.5308 | 3.5308 | 150.53 | 111.46 | 66.46 | 66.46 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051487 | 0.051487 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.8506 | 3.8506 | 172.42 | 172.42 | 72.48 | 72.48 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051487 | 0.051487 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.9920 | 3.9920 | 218.91 | 131.52 | 75.14 | 75.14 | 2 | 2 | 1.28 | 0.000024 | 0.000024 | 0.054439 | 0.054439 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.7951 | 3.7951 | 163.50 | 92.55 | 63.89 | 63.89 | 9 | 4 | 1.64 | 0.000024 | 0.000024 | 0.046684 | 0.046684 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.4841 | 3.4841 | 119.75 | 79.34 | 58.66 | 58.66 | 10 | 2 | 1.28 | 0.000024 | 0.000024 | 0.045363 | 0.045363 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.8889 | 3.8889 | 186.20 | 186.20 | 65.47 | 65.47 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.052166 | 0.052166 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.6563 | 3.6563 | 100.23 | 66.82 | 53.31 | 53.31 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.035708 | 0.035708 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.7461 | 3.7461 | 103.88 | 103.88 | 54.62 | 54.62 | 1 | 1 | 1.28 | 0.000024 | 0.000024 | 0.041284 | 0.041284 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5681 | 3.5681 | 38.83 | 38.83 | 42.48 | 42.48 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028207 | 0.028207 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5573 | 3.5573 | 51.42 | 51.42 | 29.95 | 29.95 | 3 | 0 | 1.28 | 0.000024 | 0.000024 | 0.030537 | 0.030537 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6851 | 4.6851 | 709.72 | 709.72 | 138.22 | 138.22 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.061418 | 0.061418 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6577 | 4.6577 | 623.37 | 623.37 | 128.47 | 128.47 | 5 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063565 | 0.063565 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6660 | 4.6660 | 579.45 | 579.45 | 123.37 | 123.37 | 19 | 0 | 1.28 | 0.000004 | 0.000004 | 0.059083 | 0.059083 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6498 | 4.6498 | 505.01 | 505.01 | 116.76 | 116.76 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.059964 | 0.059964 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.5488 | 4.5488 | 381.52 | 381.52 | 101.48 | 101.48 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063764 | 0.063764 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4897 | 4.4897 | 309.54 | 309.54 | 91.41 | 91.41 | 2 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063104 | 0.063104 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.3566 | 4.3566 | 157.54 | 157.54 | 65.21 | 65.21 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.055513 | 0.055513 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 4.0765 | 4.0765 | 61.51 | 61.51 | 40.75 | 40.75 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.039897 | 0.039897 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.5813 | 3.5813 | 24.65 | 24.65 | 25.79 | 25.79 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.019611 | 0.019611 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000010** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 4.4584 | 0.00 | 892.35 | 0.00 | 243.23 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.067016 | 0.067016 | 0.000000 | 0.032081 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 4.4584 | 0.00 | 993.05 | 0.00 | 240.31 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.067016 | 0.067016 | 0.000000 | 0.031123 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 4.4212 | 0.00 | 881.00 | 0.00 | 226.38 | 0 | 2 | 1.28 | 0.000036 | 0.000036 | 0.062814 | 0.062814 | 0.000000 | 0.026201 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 4.4212 | 4.4212 | 1580.72 | 907.84 | 223.30 | 223.30 | 1 | 1 | 1.28 | 0.000036 | 0.000036 | 0.062814 | 0.062814 | 0.025030 | 0.025030 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 4.4158 | 0.00 | 792.54 | 0.00 | 219.91 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062984 | 0.062984 | 0.000000 | 0.023702 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 4.4139 | 0.00 | 832.49 | 0.00 | 216.66 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.062090 | 0.062090 | 0.000000 | 0.022389 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 4.4139 | 0.00 | 821.14 | 0.00 | 213.45 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062090 | 0.062090 | 0.000000 | 0.021054 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2057 | 0.00 | 709.74 | 0.00 | 197.12 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064700 | 0.064700 | 0.000000 | 0.013594 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.1757 | 0.00 | 680.88 | 0.00 | 192.53 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061960 | 0.061960 | 0.000000 | 0.011270 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.5700 | 3.7451 | 418.05 | 404.19 | 105.99 | 154.45 | 2 | 0 | 10.20 | 0.000020 | 0.000036 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1451 | 0.00 | 451.03 | 0.00 | 170.94 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063374 | 0.063374 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.5700 | 3.7451 | 417.43 | 472.45 | 103.75 | 151.19 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1451 | 0.00 | 490.00 | 0.00 | 167.34 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 4.6680 | 4.6680 | 1430.96 | 1430.96 | 188.45 | 188.45 | 2 | 0 | 1.28 | 0.000036 | 0.000036 | 0.065140 | 0.065140 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 16 | Ship | Tanker | 110,000 | 2.5700 | 3.7274 | 395.96 | 391.33 | 101.47 | 147.17 | 2 | 0 | 10.20 | 0.000020 | 0.000036 | 0.001868 | 0.063170 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 4.1473 | 4.1473 | 1144.99 | 500.45 | 163.75 | 163.75 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062266 | 0.062266 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 4.6984 | 4.6984 | 1497.78 | 1497.78 | 185.51 | 185.51 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058063 | 0.058063 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.7347 | 0.00 | 386.79 | 0.00 | 144.07 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.001837 | 0.061299 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 4.1000 | 0.00 | 468.63 | 0.00 | 158.16 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062070 | 0.062070 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057986 | 0.057986 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 4.1000 | 0.00 | 383.11 | 0.00 | 154.35 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057246 | 0.057246 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.060442 | 0.060442 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 4.0840 | 0.00 | 439.57 | 0.00 | 149.85 | 0 | 3 | 1.28 | 0.000036 | 0.000036 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061855 | 0.061855 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 4.0840 | 0.00 | 416.02 | 0.00 | 145.86 | 0 | 2 | 1.28 | 0.000036 | 0.000036 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 4.0840 | 0.00 | 335.55 | 0.00 | 141.75 | 0 | 16 | 1.28 | 0.000036 | 0.000036 | 0.051251 | 0.051251 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 4.6420 | 4.6420 | 1189.21 | 1189.21 | 161.12 | 161.12 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057638 | 0.057638 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 4.0727 | 4.0727 | 727.55 | 303.13 | 137.14 | 137.14 | 29 | 12 | 1.28 | 0.000036 | 0.000036 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 4.6420 | 4.6420 | 1258.98 | 1258.98 | 156.31 | 156.31 | 9 | 0 | 1.28 | 0.000036 | 0.000036 | 0.059514 | 0.059514 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000000 | 0.000003 |
| 31 | Ship | Tanker | 75,000 | 2.5700 | 4.4586 | 275.47 | 412.97 | 83.79 | 145.36 | 2 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001311 | 0.052648 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 4.0727 | 4.0727 | 711.59 | 306.36 | 132.78 | 132.78 | 9 | 6 | 1.28 | 0.000036 | 0.000036 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 4.6286 | 4.6286 | 1186.37 | 1186.37 | 150.91 | 150.91 | 11 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058034 | 0.058034 | 1.000000 | 1.000000 | 0.1400 | 0.000004 | 0.000000 | 0.000004 |
| 34 | Ship | Tanker | 70,000 | 2.5700 | 4.4586 | 254.50 | 343.05 | 80.95 | 140.43 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001261 | 0.051208 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 3.9866 | 3.9866 | 682.59 | 239.71 | 125.57 | 125.57 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052334 | 0.052334 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 4.6124 | 4.6124 | 1079.14 | 1079.14 | 145.28 | 145.28 | 30 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058442 | 0.058442 | 1.000000 | 1.000000 | 0.1400 | 0.000011 | 0.000000 | 0.000011 |
| 37 | Ship | Tanker | 65,000 | 2.5700 | 4.4062 | 233.87 | 322.70 | 78.00 | 133.73 | 1 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001103 | 0.050324 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 3.9904 | 3.9904 | 584.58 | 245.52 | 121.11 | 121.11 | 35 | 15 | 1.28 | 0.000036 | 0.000036 | 0.048809 | 0.048809 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 4.6124 | 4.6124 | 1052.81 | 1052.81 | 139.99 | 139.99 | 8 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056539 | 0.056539 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000000 | 0.000003 |
| 40 | Ship | Bulk Carrier | 60,000 | 3.9502 | 3.9502 | 533.37 | 225.94 | 115.19 | 115.19 | 45 | 11 | 1.28 | 0.000036 | 0.000036 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 4.3451 | 4.3451 | 581.69 | 581.69 | 126.71 | 126.71 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.049727 | 0.049727 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 4.5743 | 4.5743 | 984.99 | 984.99 | 133.39 | 133.39 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.054292 | 0.054292 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5700 | 4.2616 | 211.56 | 300.05 | 71.75 | 118.98 | 2 | 0 | 1.64 | 0.000020 | 0.000036 | 0.000761 | 0.046097 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 4.2949 | 4.2949 | 589.30 | 261.67 | 119.91 | 119.91 | 6 | 3 | 1.28 | 0.000036 | 0.000036 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.3451 | 4.3451 | 357.13 | 357.13 | 121.31 | 121.31 | 3 | 0 | 1.28 | 0.000036 | 0.000036 | 0.048809 | 0.048809 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 4.2558 | 190.61 | 294.01 | 68.41 | 113.29 | 8 | 4 | 1.64 | 0.000020 | 0.000036 | 0.000750 | 0.045886 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 4.3054 | 4.3054 | 525.60 | 278.72 | 114.61 | 114.61 | 3 | 1 | 1.28 | 0.000036 | 0.000036 | 0.047599 | 0.047599 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 4.3451 | 4.3451 | 539.16 | 539.16 | 115.67 | 115.67 | 6 | 6 | 1.28 | 0.000036 | 0.000036 | 0.047892 | 0.047892 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000002 | 0.000004 |
| 49 | Ship | Container | 50,000 | 4.5518 | 4.5518 | 764.13 | 764.13 | 121.17 | 121.17 | 2 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051584 | 0.051584 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 4.2440 | 179.39 | 305.90 | 64.90 | 107.18 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.000728 | 0.045451 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 4.2841 | 4.2841 | 473.63 | 225.66 | 108.19 | 108.19 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.044239 | 0.044239 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 4.2786 | 4.2786 | 408.97 | 408.97 | 108.05 | 108.05 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.044059 | 0.044059 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 4.2318 | 150.54 | 223.57 | 61.19 | 100.76 | 5 | 1 | 1.64 | 0.000020 | 0.000036 | 0.000630 | 0.041601 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 4.2379 | 4.2379 | 409.81 | 207.82 | 100.90 | 100.90 | 19 | 6 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 4.2379 | 4.2379 | 368.87 | 368.87 | 100.90 | 100.90 | 6 | 1 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000000 | 0.000002 |
| 56 | Ship | Tanker | 35,000 | 4.1933 | 4.1933 | 373.13 | 196.54 | 93.39 | 93.39 | 2 | 1 | 1.64 | 0.000036 | 0.000036 | 0.039387 | 0.039387 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 4.2379 | 4.2379 | 386.33 | 198.20 | 94.39 | 94.39 | 14 | 6 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 4.2379 | 4.2379 | 219.22 | 219.22 | 94.39 | 94.39 | 11 | 5 | 1.28 | 0.000036 | 0.000036 | 0.041816 | 0.041816 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000001 | 0.000004 |
| 59 | Ship | Container | 35,000 | 4.3855 | 4.3855 | 377.08 | 377.08 | 97.67 | 97.67 | 7 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047991 | 0.047991 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000000 | 0.000002 |
| 60 | Ship | Tanker | 30,000 | 4.0894 | 4.0894 | 274.57 | 150.31 | 84.32 | 84.32 | 7 | 0 | 1.64 | 0.000036 | 0.000036 | 0.035441 | 0.035441 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 4.1728 | 4.1728 | 332.70 | 145.07 | 86.04 | 86.04 | 10 | 4 | 1.28 | 0.000036 | 0.000036 | 0.038633 | 0.038633 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 4.1440 | 4.1440 | 298.92 | 298.92 | 85.45 | 85.45 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.037551 | 0.037551 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 4.3897 | 4.3897 | 354.55 | 176.63 | 90.51 | 90.51 | 5 | 2 | 1.28 | 0.000036 | 0.000036 | 0.041149 | 0.041149 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.9703 | 3.9703 | 203.87 | 113.71 | 74.73 | 74.73 | 1 | 1 | 1.64 | 0.000036 | 0.000036 | 0.028823 | 0.028823 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 4.0466 | 4.0466 | 197.72 | 146.40 | 76.17 | 76.17 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033052 | 0.033052 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 4.0466 | 4.0466 | 190.42 | 190.42 | 76.17 | 76.17 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033052 | 0.033052 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 4.2616 | 4.2616 | 249.47 | 149.88 | 80.22 | 80.22 | 2 | 1 | 1.28 | 0.000036 | 0.000036 | 0.039156 | 0.039156 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.9600 | 3.9600 | 178.02 | 100.77 | 66.67 | 66.67 | 5 | 10 | 1.64 | 0.000036 | 0.000036 | 0.028446 | 0.028446 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.9496 | 3.9496 | 153.88 | 101.96 | 66.49 | 66.49 | 2 | 9 | 1.28 | 0.000036 | 0.000036 | 0.027436 | 0.027436 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 4.1056 | 4.1056 | 207.53 | 207.53 | 69.12 | 69.12 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.034567 | 0.034567 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.7383 | 3.7383 | 104.77 | 69.85 | 54.51 | 54.51 | 1 | 0 | 1.64 | 0.000036 | 0.000036 | 0.018944 | 0.018944 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.8827 | 3.8827 | 111.59 | 111.59 | 56.61 | 56.61 | 2 | 2 | 1.28 | 0.000036 | 0.000036 | 0.023934 | 0.023934 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000001 |
| 73 | Ship | General Cargo | 10,000 | 3.5932 | 3.5932 | 39.38 | 39.38 | 42.78 | 42.78 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.013574 | 0.013574 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5752 | 3.5752 | 51.94 | 51.94 | 30.10 | 30.10 | 2 | 0 | 1.28 | 0.000036 | 0.000036 | 0.014640 | 0.014640 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6540 | 4.6540 | 700.33 | 700.33 | 137.30 | 137.30 | 1 | 0 | 1.28 | 0.000006 | 0.000006 | 0.053600 | 0.053600 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6217 | 4.6217 | 613.76 | 613.76 | 127.47 | 127.47 | 5 | 0 | 1.28 | 0.000006 | 0.000006 | 0.054428 | 0.054428 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6310 | 4.6310 | 570.79 | 570.79 | 122.45 | 122.45 | 19 | 0 | 1.28 | 0.000006 | 0.000006 | 0.050608 | 0.050608 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6128 | 4.6128 | 497.00 | 497.00 | 115.83 | 115.83 | 10 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051012 | 0.051012 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.4979 | 4.4979 | 373.03 | 373.03 | 100.35 | 100.35 | 11 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051765 | 0.051765 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4296 | 4.4296 | 301.31 | 301.31 | 90.19 | 90.19 | 3 | 0 | 1.28 | 0.000006 | 0.000006 | 0.049628 | 0.049628 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.2730 | 4.2730 | 151.55 | 151.55 | 63.96 | 63.96 | 3 | 0 | 1.28 | 0.000006 | 0.000006 | 0.040202 | 0.040202 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.9292 | 3.9292 | 57.14 | 57.14 | 39.27 | 39.27 | 1 | 0 | 1.28 | 0.000006 | 0.000006 | 0.023659 | 0.023659 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.2707 | 3.2707 | 20.56 | 20.56 | 23.56 | 23.56 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.007671 | 0.007671 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000042** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 4.4584 | 0.00 | 892.35 | 0.00 | 243.23 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.067016 | 0.067016 | 0.000000 | 0.032081 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 4.4584 | 0.00 | 993.05 | 0.00 | 240.31 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.067016 | 0.067016 | 0.000000 | 0.031123 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 4.4212 | 0.00 | 881.00 | 0.00 | 226.38 | 0 | 2 | 1.28 | 0.000028 | 0.000028 | 0.062814 | 0.062814 | 0.000000 | 0.026201 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 4.4212 | 4.4212 | 1580.72 | 907.84 | 223.30 | 223.30 | 1 | 1 | 1.28 | 0.000028 | 0.000028 | 0.062814 | 0.062814 | 0.025030 | 0.025030 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 4.4158 | 0.00 | 792.54 | 0.00 | 219.91 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062984 | 0.062984 | 0.000000 | 0.023702 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 4.4139 | 0.00 | 832.49 | 0.00 | 216.66 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.062090 | 0.062090 | 0.000000 | 0.022389 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 4.4139 | 0.00 | 821.14 | 0.00 | 213.45 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062090 | 0.062090 | 0.000000 | 0.021054 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2057 | 0.00 | 709.74 | 0.00 | 197.12 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064700 | 0.064700 | 0.000000 | 0.013594 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.1757 | 0.00 | 680.88 | 0.00 | 192.53 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061960 | 0.061960 | 0.000000 | 0.011270 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 2.5700 | 3.7451 | 418.05 | 404.19 | 105.99 | 154.45 | 2 | 0 | 10.20 | 0.000015 | 0.000028 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1451 | 0.00 | 451.03 | 0.00 | 170.94 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063374 | 0.063374 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 2.5700 | 3.7451 | 417.43 | 472.45 | 103.75 | 151.19 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1451 | 0.00 | 490.00 | 0.00 | 167.34 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 4.6680 | 4.6680 | 1430.96 | 1430.96 | 188.45 | 188.45 | 2 | 0 | 1.28 | 0.000028 | 0.000028 | 0.065140 | 0.065140 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 16 | Ship | Tanker | 110,000 | 2.5700 | 3.7274 | 395.96 | 391.33 | 101.47 | 147.17 | 2 | 0 | 10.20 | 0.000015 | 0.000028 | 0.001868 | 0.063170 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 4.1473 | 4.1473 | 1144.99 | 500.45 | 163.75 | 163.75 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062266 | 0.062266 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 4.6984 | 4.6984 | 1497.78 | 1497.78 | 185.51 | 185.51 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058063 | 0.058063 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.7347 | 0.00 | 386.79 | 0.00 | 144.07 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.001837 | 0.061299 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 4.1000 | 0.00 | 468.63 | 0.00 | 158.16 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062070 | 0.062070 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057986 | 0.057986 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 4.1000 | 0.00 | 383.11 | 0.00 | 154.35 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057246 | 0.057246 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.060442 | 0.060442 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 4.0840 | 0.00 | 439.57 | 0.00 | 149.85 | 0 | 3 | 1.28 | 0.000028 | 0.000028 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061855 | 0.061855 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 4.0840 | 0.00 | 416.02 | 0.00 | 145.86 | 0 | 2 | 1.28 | 0.000028 | 0.000028 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 4.0840 | 0.00 | 335.55 | 0.00 | 141.75 | 0 | 16 | 1.28 | 0.000028 | 0.000028 | 0.051251 | 0.051251 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 4.6420 | 4.6420 | 1189.21 | 1189.21 | 161.12 | 161.12 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057638 | 0.057638 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 4.0727 | 4.0727 | 727.55 | 303.13 | 137.14 | 137.14 | 29 | 12 | 1.28 | 0.000028 | 0.000028 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 4.6420 | 4.6420 | 1258.98 | 1258.98 | 156.31 | 156.31 | 9 | 0 | 1.28 | 0.000028 | 0.000028 | 0.059514 | 0.059514 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000000 | 0.000003 |
| 31 | Ship | Tanker | 75,000 | 2.5700 | 4.4586 | 275.47 | 412.97 | 83.79 | 145.36 | 2 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001311 | 0.052648 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 4.0727 | 4.0727 | 711.59 | 306.36 | 132.78 | 132.78 | 9 | 6 | 1.28 | 0.000028 | 0.000028 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 4.6286 | 4.6286 | 1186.37 | 1186.37 | 150.91 | 150.91 | 11 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058034 | 0.058034 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000000 | 0.000003 |
| 34 | Ship | Tanker | 70,000 | 2.5700 | 4.4586 | 254.50 | 343.05 | 80.95 | 140.43 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001261 | 0.051208 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 3.9866 | 3.9866 | 682.59 | 239.71 | 125.57 | 125.57 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052334 | 0.052334 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 4.6124 | 4.6124 | 1079.14 | 1079.14 | 145.28 | 145.28 | 30 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058442 | 0.058442 | 1.000000 | 1.000000 | 0.1400 | 0.000009 | 0.000000 | 0.000009 |
| 37 | Ship | Tanker | 65,000 | 2.5700 | 4.4062 | 233.87 | 322.70 | 78.00 | 133.73 | 1 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001103 | 0.050324 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 3.9904 | 3.9904 | 584.58 | 245.52 | 121.11 | 121.11 | 35 | 15 | 1.28 | 0.000028 | 0.000028 | 0.048809 | 0.048809 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 4.6124 | 4.6124 | 1052.81 | 1052.81 | 139.99 | 139.99 | 8 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056539 | 0.056539 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000000 | 0.000002 |
| 40 | Ship | Bulk Carrier | 60,000 | 3.9502 | 3.9502 | 533.37 | 225.94 | 115.19 | 115.19 | 45 | 11 | 1.28 | 0.000028 | 0.000028 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 4.3451 | 4.3451 | 581.69 | 581.69 | 126.71 | 126.71 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.049727 | 0.049727 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 4.5743 | 4.5743 | 984.99 | 984.99 | 133.39 | 133.39 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.054292 | 0.054292 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 2.5700 | 4.2616 | 211.56 | 300.05 | 71.75 | 118.98 | 2 | 0 | 1.64 | 0.000015 | 0.000028 | 0.000761 | 0.046097 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 4.2949 | 4.2949 | 589.30 | 261.67 | 119.91 | 119.91 | 6 | 3 | 1.28 | 0.000028 | 0.000028 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.3451 | 4.3451 | 357.13 | 357.13 | 121.31 | 121.31 | 3 | 0 | 1.28 | 0.000028 | 0.000028 | 0.048809 | 0.048809 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 4.2558 | 190.61 | 294.01 | 68.41 | 113.29 | 8 | 4 | 1.64 | 0.000015 | 0.000028 | 0.000750 | 0.045886 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 4.3054 | 4.3054 | 525.60 | 278.72 | 114.61 | 114.61 | 3 | 1 | 1.28 | 0.000028 | 0.000028 | 0.047599 | 0.047599 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 4.3451 | 4.3451 | 539.16 | 539.16 | 115.67 | 115.67 | 6 | 6 | 1.28 | 0.000028 | 0.000028 | 0.047892 | 0.047892 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000001 | 0.000003 |
| 49 | Ship | Container | 50,000 | 4.5518 | 4.5518 | 764.13 | 764.13 | 121.17 | 121.17 | 2 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051584 | 0.051584 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 4.2440 | 179.39 | 305.90 | 64.90 | 107.18 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.000728 | 0.045451 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 4.2841 | 4.2841 | 473.63 | 225.66 | 108.19 | 108.19 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.044239 | 0.044239 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 4.2786 | 4.2786 | 408.97 | 408.97 | 108.05 | 108.05 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.044059 | 0.044059 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 4.2318 | 150.54 | 223.57 | 61.19 | 100.76 | 5 | 1 | 1.64 | 0.000015 | 0.000028 | 0.000630 | 0.041601 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 4.2379 | 4.2379 | 409.81 | 207.82 | 100.90 | 100.90 | 19 | 6 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 4.2379 | 4.2379 | 368.87 | 368.87 | 100.90 | 100.90 | 6 | 1 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000002 |
| 56 | Ship | Tanker | 35,000 | 4.1933 | 4.1933 | 373.13 | 196.54 | 93.39 | 93.39 | 2 | 1 | 1.64 | 0.000028 | 0.000028 | 0.039387 | 0.039387 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 4.2379 | 4.2379 | 386.33 | 198.20 | 94.39 | 94.39 | 14 | 6 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 4.2379 | 4.2379 | 219.22 | 219.22 | 94.39 | 94.39 | 11 | 5 | 1.28 | 0.000028 | 0.000028 | 0.041816 | 0.041816 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000001 | 0.000003 |
| 59 | Ship | Container | 35,000 | 4.3855 | 4.3855 | 377.08 | 377.08 | 97.67 | 97.67 | 7 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047991 | 0.047991 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000000 | 0.000002 |
| 60 | Ship | Tanker | 30,000 | 4.0894 | 4.0894 | 274.57 | 150.31 | 84.32 | 84.32 | 7 | 0 | 1.64 | 0.000028 | 0.000028 | 0.035441 | 0.035441 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 4.1728 | 4.1728 | 332.70 | 145.07 | 86.04 | 86.04 | 10 | 4 | 1.28 | 0.000028 | 0.000028 | 0.038633 | 0.038633 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 4.1440 | 4.1440 | 298.92 | 298.92 | 85.45 | 85.45 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.037551 | 0.037551 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 4.3897 | 4.3897 | 354.55 | 176.63 | 90.51 | 90.51 | 5 | 2 | 1.28 | 0.000028 | 0.000028 | 0.041149 | 0.041149 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.9703 | 3.9703 | 203.87 | 113.71 | 74.73 | 74.73 | 1 | 1 | 1.64 | 0.000028 | 0.000028 | 0.028823 | 0.028823 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 4.0466 | 4.0466 | 197.72 | 146.40 | 76.17 | 76.17 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033052 | 0.033052 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 4.0466 | 4.0466 | 190.42 | 190.42 | 76.17 | 76.17 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033052 | 0.033052 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 4.2616 | 4.2616 | 249.47 | 149.88 | 80.22 | 80.22 | 2 | 1 | 1.28 | 0.000028 | 0.000028 | 0.039156 | 0.039156 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.9600 | 3.9600 | 178.02 | 100.77 | 66.67 | 66.67 | 5 | 10 | 1.64 | 0.000028 | 0.000028 | 0.028446 | 0.028446 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.9496 | 3.9496 | 153.88 | 101.96 | 66.49 | 66.49 | 2 | 9 | 1.28 | 0.000028 | 0.000028 | 0.027436 | 0.027436 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 4.1056 | 4.1056 | 207.53 | 207.53 | 69.12 | 69.12 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.034567 | 0.034567 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.7383 | 3.7383 | 104.77 | 69.85 | 54.51 | 54.51 | 1 | 0 | 1.64 | 0.000028 | 0.000028 | 0.018944 | 0.018944 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.8827 | 3.8827 | 111.59 | 111.59 | 56.61 | 56.61 | 2 | 2 | 1.28 | 0.000028 | 0.000028 | 0.023934 | 0.023934 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5932 | 3.5932 | 39.38 | 39.38 | 42.78 | 42.78 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.013574 | 0.013574 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5752 | 3.5752 | 51.94 | 51.94 | 30.10 | 30.10 | 2 | 0 | 1.28 | 0.000028 | 0.000028 | 0.014640 | 0.014640 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6540 | 4.6540 | 700.33 | 700.33 | 137.30 | 137.30 | 1 | 0 | 1.28 | 0.000005 | 0.000005 | 0.053600 | 0.053600 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6217 | 4.6217 | 613.76 | 613.76 | 127.47 | 127.47 | 5 | 0 | 1.28 | 0.000005 | 0.000005 | 0.054428 | 0.054428 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6310 | 4.6310 | 570.79 | 570.79 | 122.45 | 122.45 | 19 | 0 | 1.28 | 0.000005 | 0.000005 | 0.050608 | 0.050608 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6128 | 4.6128 | 497.00 | 497.00 | 115.83 | 115.83 | 10 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051012 | 0.051012 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.4979 | 4.4979 | 373.03 | 373.03 | 100.35 | 100.35 | 11 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051765 | 0.051765 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4296 | 4.4296 | 301.31 | 301.31 | 90.19 | 90.19 | 3 | 0 | 1.28 | 0.000005 | 0.000005 | 0.049628 | 0.049628 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.2730 | 4.2730 | 151.55 | 151.55 | 63.96 | 63.96 | 3 | 0 | 1.28 | 0.000005 | 0.000005 | 0.040202 | 0.040202 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.9292 | 3.9292 | 57.14 | 57.14 | 39.27 | 39.27 | 1 | 0 | 1.28 | 0.000005 | 0.000005 | 0.023659 | 0.023659 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.2707 | 3.2707 | 20.56 | 20.56 | 23.56 | 23.56 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.007671 | 0.007671 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000032** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

## ANNUAL FREQUENCY OF COLLAPSE - SUMMARY (WATER ELEVATION 1.6 CD)

| Pier ID | Description | Ultimate Lateral Capacity, H (MN) | | Overall Annual Frequency of Collapse, AF | | | Return Period | % Risk |
|---|---|---|---|---|---|---|---|---|
| | | Foundation | Tower | Inbound | Outbound | Total | | |
| 1 | North Tower | **33** | **0** | 0.00000000 | 0.00000000 | 0.00000000 | - | 0% |
| 2 | South Tower | **173** | **0** | 0.00000551 | 0.00002497 | 0.00003048 | 32,808 | 100% |
| | | | **Total for Bridge:** | 0.00000551 | 0.00002497 | 0.00003048 | **32,808** | **100%** |

**Bridge Type:** **Class I**

**Minimum Return Period:** **10,000**

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# VESSEL FLEET CHARACTERISTICS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Size (m) | | Vessel Drafts (m) | | | | Vessel Displacement (tonnes) | | Channel Width, C (m) | Centerline Vessel Transit Path to Edge of Channel, $x_C$ (m) | | | | Minimum Design Impact Speed, $V_{min}$ (m/sec) | Standard Deviation, σ (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length Overall, LOA | Beam, B | Operational Loaded, $D_O$ | Ballasted | | | Loaded, $W_L$ | Ballasted, $W_E$ | | Inbound | | Outbound | | | Loaded | Ballasted |
| | | | | | | | Stern, $D_{ES}$ | Bow, $D_{EB}$ | Average, $D_{AVG}$ | | | | Pier 1 | Pier 2 | Pier 1 | Pier 2 | | | |
| 1 | Ship | Bulk Carrier | 210,000 | 300 | 50 | 15.0 | 9.2 | 5.0 | 7.1 | 180,650 | 85,510 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 2 | Ship | Bulk Carrier | 205,000 | 300 | 50 | 15.0 | 10.0 | 5.8 | 7.9 | 180,670 | 95,160 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 3 | Ship | Bulk Carrier | 185,000 | 292 | 45 | 15.0 | 10.2 | 6.1 | 8.2 | 158,000 | 85,850 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 292 | 292 |
| 4 | Ship | Bulk Carrier | 180,000 | 292 | 45 | 12.3 | 10.4 | 6.3 | 8.4 | 129,390 | 87,840 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 292 | 292 |
| 5 | Ship | Bulk Carrier | 175,000 | 289 | 45 | 12.6 | 9.5 | 5.4 | 7.5 | 130,940 | 77,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 289 | 289 |
| 6 | Ship | Bulk Carrier | 170,000 | 288 | 44 | 14.5 | 10.1 | 6.0 | 8.1 | 146,610 | 81,390 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 288 | 288 |
| 7 | Ship | Bulk Carrier | 165,000 | 288 | 44 | 15.0 | 10.0 | 5.9 | 8.0 | 151,460 | 80,280 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 288 | 288 |
| 8 | Ship | Bulk Carrier | 155,000 | 273 | 46 | 15.0 | 9.6 | 5.7 | 7.7 | 149,850 | 76,430 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 273 | 273 |
| 9 | Ship | Bulk Carrier | 150,000 | 269 | 43 | 15.0 | 10.0 | 6.2 | 8.1 | 137,740 | 74,380 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 269 | 269 |
| 10 | Ship | Tanker | 120,000 | 250 | 44 | 11.9 | 8.2 | 4.7 | 6.5 | 101,270 | 54,890 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 250 |
| 11 | Ship | Bulk Carrier | 120,000 | 254 | 43 | 14.5 | 7.6 | 4.0 | 5.8 | 124,980 | 50,000 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 254 | 254 |
| 12 | Ship | Container | 120,000 | 324 | 48 | 12.6 | 12.6 | 12.6 | 12.6 | 120,230 | 120,230 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 324 | 324 |
| 13 | Ship | Tanker | 115,000 | 250 | 44 | 11.9 | 9.3 | 5.8 | 7.6 | 101,120 | 64,160 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 250 |
| 14 | Ship | Bulk Carrier | 115,000 | 254 | 43 | 14.7 | 8.1 | 4.5 | 6.3 | 126,740 | 54,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 254 | 254 |
| 15 | Ship | Container | 115,000 | 300 | 48 | 11.9 | 11.9 | 11.9 | 11.9 | 105,070 | 105,070 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 16 | Ship | Tanker | 110,000 | 240 | 44 | 11.8 | 8.3 | 4.9 | 6.6 | 95,920 | 53,650 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 240 |
| 17 | Ship | Bulk Carrier | 110,000 | 255 | 43 | 12.3 | 8.2 | 4.6 | 6.4 | 106,510 | 55,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 255 | 255 |
| 18 | Ship | Container | 110,000 | 334 | 43 | 12.3 | 12.3 | 12.3 | 12.3 | 108,560 | 108,560 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 334 | 334 |
| 19 | Ship | Tanker | 105,000 | 244 | 42 | 13.0 | 8.4 | 5.0 | 6.7 | 102,480 | 52,820 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 244 |
| 20 | Ship | Bulk Carrier | 105,000 | 235 | 43 | 14.0 | 8.3 | 5.0 | 6.7 | 111,780 | 53,100 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 235 | 235 |
| 21 | Ship | Container | 105,000 | 335 | 43 | 12.6 | 12.6 | 12.6 | 12.6 | 111,550 | 111,550 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 335 | 335 |
| 22 | Ship | Bulk Carrier | 100,000 | 235 | 38 | 13.5 | 7.8 | 4.5 | 6.2 | 95,280 | 43,410 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 235 | 235 |
| 23 | Ship | Container | 100,000 | 338 | 46 | 12.8 | 12.8 | 12.8 | 12.8 | 122,370 | 122,370 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 338 | 338 |
| 24 | Ship | Bulk Carrier | 95,000 | 229 | 38 | 12.8 | 8.9 | 5.7 | 7.3 | 88,020 | 50,200 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 25 | Ship | Container | 95,000 | 320 | 46 | 13.6 | 13.6 | 13.6 | 13.6 | 122,750 | 122,750 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 320 | 320 |
| 26 | Ship | Bulk Carrier | 90,000 | 229 | 38 | 12.6 | 8.5 | 5.3 | 6.9 | 86,760 | 47,510 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 27 | Ship | Bulk Carrier | 85,000 | 229 | 32 | 12.7 | 8.2 | 5.0 | 6.6 | 73,730 | 38,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 28 | Ship | Container | 85,000 | 300 | 40 | 12.0 | 12.0 | 12.0 | 12.0 | 88,300 | 88,300 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 300 | 300 |
| 29 | Ship | Bulk Carrier | 80,000 | 225 | 32 | 12.3 | 7.7 | 4.5 | 6.1 | 70,180 | 34,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 225 | 225 |
| 30 | Ship | Container | 80,000 | 300 | 42 | 12.1 | 12.1 | 12.1 | 12.1 | 93,480 | 93,480 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 300 | 300 |
| 31 | Ship | Tanker | 75,000 | 228 | 34 | 11.3 | 8.3 | 5.1 | 6.7 | 66,730 | 39,570 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 228 |
| 32 | Ship | Bulk Carrier | 75,000 | 225 | 32 | 12.1 | 7.8 | 4.6 | 6.2 | 68,640 | 35,180 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 225 | 225 |
| 33 | Ship | Container | 75,000 | 293 | 40 | 12.3 | 12.3 | 12.3 | 12.3 | 88,600 | 88,600 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 293 | 293 |
| 34 | Ship | Tanker | 70,000 | 228 | 32 | 11.0 | 7.4 | 4.2 | 5.8 | 62,330 | 32,870 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 228 |
| 35 | Ship | Bulk Carrier | 70,000 | 199 | 36 | 12.2 | 6.5 | 3.7 | 5.1 | 68,720 | 28,730 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 199 | 199 |
| 36 | Ship | Container | 70,000 | 285 | 40 | 11.6 | 11.6 | 11.6 | 11.6 | 81,160 | 81,160 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 37 | Ship | Tanker | 65,000 | 214 | 32 | 10.9 | 7.5 | 4.5 | 6.0 | 57,520 | 31,660 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 73 | 214 |
| 38 | Ship | Bulk Carrier | 65,000 | 200 | 32 | 11.8 | 7.3 | 4.5 | 5.9 | 58,740 | 29,370 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 39 | Ship | Container | 65,000 | 285 | 38 | 12.2 | 12.2 | 12.2 | 12.2 | 79,180 | 79,180 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 40 | Ship | Bulk Carrier | 60,000 | 190 | 32 | 11.6 | 7.2 | 4.5 | 5.9 | 54,690 | 27,580 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 190 | 190 |
| 41 | Ship | General Cargo | 60,000 | 200 | 33 | 11.0 | 11.0 | 11.0 | 11.0 | 49,840 | 49,840 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 42 | Ship | Container | 60,000 | 268 | 35 | 12.0 | 12.0 | 12.0 | 12.0 | 75,320 | 75,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 268 | 268 |
| 43 | Ship | Tanker | 55,000 | 184 | 32 | 11.4 | 8.3 | 5.7 | 7.0 | 51,250 | 31,470 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 184 |
| 44 | Ship | Bulk Carrier | 55,000 | 190 | 32 | 11.0 | 7.1 | 4.4 | 5.8 | 51,680 | 27,020 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 190 | 190 |
| 45 | Ship | General Cargo | 55,000 | 200 | 32 | 8.2 | 8.2 | 8.2 | 8.2 | 36,030 | 36,030 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 46 | Ship | Tanker | 50,000 | 183 | 32 | 10.6 | 8.2 | 5.6 | 6.9 | 47,500 | 30,920 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 183 |
| 47 | Ship | Bulk Carrier | 50,000 | 192 | 32 | 10.1 | 7.4 | 4.7 | 6.1 | 47,810 | 28,640 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 192 | 192 |
| 48 | Ship | General Cargo | 50,000 | 200 | 31 | 10.9 | 10.9 | 10.9 | 10.9 | 46,390 | 46,390 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 49 | Ship | Container | 50,000 | 259 | 32 | 11.3 | 11.3 | 11.3 | 11.3 | 59,010 | 59,010 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 259 | 259 |

# VESSEL FLEET CHARACTERISTICS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Size (m) | | Vessel Drafts (m) | | | | Vessel Displacement (tonnes) | | Channel Width, C (m) | Centerline Vessel Transit Path to Edge of Channel, $x_C$ (m) | | | | Minimum Design Impact Speed, $V_{min}$ (m/sec) | Standard Deviation, σ (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length Overall, LOA | Beam, B | Operational Loaded, $D_O$ | Ballasted | | | Loaded, $W_L$ | Ballasted, $W_E$ | | Inbound | | Outbound | | | Loaded | Ballasted |
| | | | | | | | Stern, $D_{ES}$ | Bow, $D_{EB}$ | Average, $D_{AVG}$ | | | | Pier 1 | Pier 2 | Pier 1 | Pier 2 | | | |
| 50 | Ship | Tanker | 45,000 | 181 | 32 | 10.3 | 8.6 | 6.1 | 7.4 | 45,340 | 32,350 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 181 |
| 51 | Ship | Bulk Carrier | 45,000 | 188 | 29 | 10.3 | 6.9 | 4.3 | 5.6 | 43,080 | 23,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 188 | 188 |
| 52 | Ship | General Cargo | 45,000 | 187 | 29 | 10.1 | 10.1 | 10.1 | 10.1 | 37,670 | 37,670 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 187 | 187 |
| 53 | Ship | Tanker | 40,000 | 179 | 28 | 10.1 | 7.5 | 5.0 | 6.3 | 38,430 | 23,780 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 70 | 179 |
| 54 | Ship | Bulk Carrier | 40,000 | 180 | 30 | 9.6 | 6.6 | 4.1 | 5.4 | 39,540 | 22,040 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 55 | Ship | General Cargo | 40,000 | 180 | 30 | 9.6 | 9.6 | 9.6 | 9.6 | 35,590 | 35,590 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 56 | Ship | Tanker | 35,000 | 173 | 27 | 10.2 | 7.3 | 4.9 | 6.1 | 35,600 | 21,290 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 173 | 173 |
| 57 | Ship | Bulk Carrier | 35,000 | 180 | 30 | 9.3 | 6.4 | 3.9 | 5.2 | 37,960 | 21,020 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 58 | Ship | General Cargo | 35,000 | 180 | 28 | 6.7 | 6.7 | 6.7 | 6.7 | 23,250 | 23,250 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 59 | Ship | Container | 35,000 | 209 | 30 | 9.3 | 9.3 | 9.3 | 9.3 | 34,600 | 34,600 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 209 | 209 |
| 60 | Ship | Tanker | 30,000 | 159 | 27 | 9.2 | 6.5 | 4.3 | 5.4 | 29,160 | 17,120 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 159 | 159 |
| 61 | Ship | Bulk Carrier | 30,000 | 170 | 27 | 9.6 | 5.8 | 3.4 | 4.6 | 33,110 | 15,870 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 170 | 170 |
| 62 | Ship | General Cargo | 30,000 | 166 | 27 | 9.7 | 9.7 | 9.7 | 9.7 | 29,990 | 29,990 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 166 | 166 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 210 | 23 | 9.3 | 5.0 | 5.0 | 5.0 | 32,470 | 17,460 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 210 | 210 |
| 64 | Ship | Tanker | 25,000 | 146 | 24 | 9.2 | 6.5 | 4.5 | 5.5 | 22,970 | 13,740 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 146 | 146 |
| 65 | Ship | Bulk Carrier | 25,000 | 154 | 26 | 7.7 | 6.8 | 4.6 | 5.7 | 23,000 | 17,030 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 154 | 154 |
| 66 | Ship | General Cargo | 25,000 | 154 | 26 | 8.1 | 8.1 | 8.1 | 8.1 | 22,150 | 22,150 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 154 | 154 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 184 | 24 | 8.3 | 5.0 | 5.0 | 5.0 | 26,090 | 15,720 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 184 | 184 |
| 68 | Ship | Tanker | 20,000 | 145 | 24 | 8.7 | 6.1 | 4.1 | 5.1 | 20,880 | 12,240 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 145 | 145 |
| 69 | Ship | Bulk Carrier | 20,000 | 144 | 23 | 7.7 | 6.1 | 4.1 | 5.1 | 18,790 | 12,450 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 144 | 144 |
| 70 | Ship | General Cargo | 20,000 | 161 | 25 | 8.5 | 8.5 | 8.5 | 8.5 | 23,000 | 23,000 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 161 | 161 |
| 71 | Ship | Tanker | 15,000 | 127 | 20 | 8.1 | 6.3 | 4.5 | 5.4 | 14,280 | 9,520 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 127 | 127 |
| 72 | Ship | General Cargo | 15,000 | 138 | 21 | 7.2 | 7.2 | 7.2 | 7.2 | 14,100 | 14,100 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 138 | 138 |
| 73 | Ship | General Cargo | 10,000 | 118 | 16 | 4.5 | 4.5 | 4.5 | 4.5 | 5,810 | 5,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 118 | 118 |
| 74 | Ship | General Cargo | 5,000 | 117 | 20 | 4.7 | 4.7 | 4.7 | 4.7 | 7,740 | 7,740 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 117 | 117 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 317 | 37 | 8.3 | 8.3 | 8.3 | 8.3 | 61,410 | 61,410 | 142.0 | 93.5 | 48.5 | 57.0 | 85.0 | 2.57 | 317 | 317 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 290 | 36 | 8.5 | 8.5 | 8.5 | 8.5 | 53,680 | 53,680 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 290 | 290 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 294 | 32 | 8.6 | 8.6 | 8.6 | 8.6 | 49,330 | 49,330 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 294 | 294 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 285 | 32 | 8.0 | 8.0 | 8.0 | 8.0 | 44,490 | 44,490 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 240 | 32 | 8.1 | 8.1 | 8.1 | 8.1 | 35,120 | 35,120 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 240 | 240 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 220 | 31 | 7.7 | 7.7 | 7.7 | 7.7 | 29,250 | 29,250 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 220 | 220 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 186 | 25 | 6.1 | 6.1 | 6.1 | 6.1 | 15,810 | 15,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 186 | 186 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 142 | 18 | 4.9 | 4.9 | 4.9 | 4.9 | 7,050 | 7,050 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 142 | 142 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 103 | 15 | 4.1 | 4.1 | 4.1 | 4.1 | 3,660 | 3,660 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 103 | 103 |

**Notes:**

Weight of Water ($W_W$) = **0.9854** $m^3$/tonne (used to determine ship loaded/ballasted displacement tonnage based on approximate salinity of water in Vancouver Harbor)

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# VESSEL FLEET ANNUAL TRIP FREQUENCY

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Annual Number of Trips (N) | | | | | | Existing Total Trips | Growth Factor [1] | Future Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | | Outbound | | | | | |
| | | | | Loaded | Ballasted | Total | Loaded | Ballasted | Total | | | |
| 1 | Ship | Bulk Carrier | 210,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 2 | Ship | Bulk Carrier | 205,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 3 | Ship | Bulk Carrier | 185,000 | 0 | 3 | 3 | 0 | 3 | 3 | 6 | 1.28 | 8 |
| 4 | Ship | Bulk Carrier | 180,000 | 0 | 1 | 1 | 1 | 1 | 2 | 3 | 1.28 | 4 |
| 5 | Ship | Bulk Carrier | 175,000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 6 | Ship | Bulk Carrier | 170,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 1.28 | 3 |
| 7 | Ship | Bulk Carrier | 165,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 8 | Ship | Bulk Carrier | 155,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 9 | Ship | Bulk Carrier | 150,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 10 | Ship | Tanker | 120,000 | 0 | 3 | 3 | 2 | 0 | 2 | 5 | 10.20 | 51 |
| 11 | Ship | Bulk Carrier | 120,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 12 | Ship | Container | 120,000 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 13 | Ship | Tanker | 115,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 10.20 | 10 |
| 14 | Ship | Bulk Carrier | 115,000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 15 | Ship | Container | 115,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 16 | Ship | Tanker | 110,000 | 0 | 2 | 2 | 3 | 0 | 3 | 5 | 10.20 | 51 |
| 17 | Ship | Bulk Carrier | 110,000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 18 | Ship | Container | 110,000 | 1 | 0 | 1 | 2 | 0 | 2 | 3 | 1.28 | 4 |
| 19 | Ship | Tanker | 105,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10.20 | 0 |
| 20 | Ship | Bulk Carrier | 105,000 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1.28 | 1 |
| 21 | Ship | Container | 105,000 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1.28 | 13 |
| 22 | Ship | Bulk Carrier | 100,000 | 0 | 2 | 2 | 1 | 0 | 1 | 3 | 1.28 | 4 |
| 23 | Ship | Container | 100,000 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 1.28 | 28 |
| 24 | Ship | Bulk Carrier | 95,000 | 0 | 5 | 5 | 2 | 2 | 4 | 9 | 1.28 | 12 |
| 25 | Ship | Container | 95,000 | 1 | 0 | 1 | 2 | 0 | 2 | 3 | 1.28 | 4 |
| 26 | Ship | Bulk Carrier | 90,000 | 1 | 4 | 5 | 2 | 3 | 5 | 10 | 1.28 | 13 |
| 27 | Ship | Bulk Carrier | 85,000 | 6 | 39 | 45 | 29 | 16 | 45 | 90 | 1.28 | 115 |
| 28 | Ship | Container | 85,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 29 | Ship | Bulk Carrier | 80,000 | 8 | 33 | 41 | 29 | 12 | 41 | 82 | 1.28 | 105 |
| 30 | Ship | Container | 80,000 | 9 | 0 | 9 | 9 | 0 | 9 | 18 | 1.28 | 23 |
| 31 | Ship | Tanker | 75,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 1.64 | 7 |
| 32 | Ship | Bulk Carrier | 75,000 | 1 | 13 | 14 | 8 | 6 | 14 | 28 | 1.28 | 36 |
| 33 | Ship | Container | 75,000 | 12 | 0 | 12 | 12 | 0 | 12 | 24 | 1.28 | 31 |
| 34 | Ship | Tanker | 70,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.64 | 0 |
| 35 | Ship | Bulk Carrier | 70,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 36 | Ship | Container | 70,000 | 30 | 0 | 30 | 30 | 0 | 30 | 60 | 1.28 | 77 |
| 37 | Ship | Tanker | 65,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 38 | Ship | Bulk Carrier | 65,000 | 13 | 35 | 48 | 34 | 14 | 48 | 96 | 1.28 | 123 |
| 39 | Ship | Container | 65,000 | 9 | 0 | 9 | 9 | 0 | 9 | 18 | 1.28 | 23 |
| 40 | Ship | Bulk Carrier | 60,000 | 12 | 44 | 56 | 44 | 12 | 56 | 112 | 1.28 | 143 |
| 41 | Ship | General Cargo | 60,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 42 | Ship | Container | 60,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 43 | Ship | Tanker | 55,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 1.64 | 7 |
| 44 | Ship | Bulk Carrier | 55,000 | 2 | 8 | 10 | 7 | 3 | 10 | 20 | 1.28 | 26 |
| 45 | Ship | General Cargo | 55,000 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| 46 | Ship | Tanker | 50,000 | 3 | 8 | 11 | 8 | 4 | 12 | 23 | 1.64 | 38 |
| 47 | Ship | Bulk Carrier | 50,000 | 2 | 3 | 5 | 3 | 1 | 4 | 9 | 1.28 | 12 |
| 48 | Ship | General Cargo | 50,000 | 6 | 6 | 12 | 6 | 6 | 12 | 24 | 1.28 | 31 |
| 49 | Ship | Container | 50,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# VESSEL FLEET ANNUAL TRIP FREQUENCY

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Annual Number of Trips (N) | | | | | | Existing Total Trips | Growth Factor [1] | Future Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | | Outbound | | | | | |
| | | | | Loaded | Ballasted | Total | Loaded | Ballasted | Total | | | |
| 50 | Ship | Tanker | 45,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 51 | Ship | Bulk Carrier | 45,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 52 | Ship | General Cargo | 45,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 53 | Ship | Tanker | 40,000 | 0 | 4 | 4 | 4 | 0 | 4 | 8 | 1.64 | 13 |
| 54 | Ship | Bulk Carrier | 40,000 | 6 | 20 | 26 | 20 | 6 | 26 | 52 | 1.28 | 67 |
| 55 | Ship | General Cargo | 40,000 | 2 | 7 | 9 | 6 | 2 | 8 | 17 | 1.28 | 22 |
| 56 | Ship | Tanker | 35,000 | 1 | 2 | 3 | 2 | 1 | 3 | 6 | 1.64 | 10 |
| 57 | Ship | Bulk Carrier | 35,000 | 6 | 12 | 18 | 13 | 6 | 19 | 37 | 1.28 | 47 |
| 58 | Ship | General Cargo | 35,000 | 5 | 12 | 17 | 12 | 5 | 17 | 34 | 1.28 | 44 |
| 59 | Ship | Container | 35,000 | 6 | 0 | 6 | 6 | 0 | 6 | 12 | 1.28 | 15 |
| 60 | Ship | Tanker | 30,000 | 1 | 7 | 8 | 7 | 0 | 7 | 15 | 1.64 | 25 |
| 61 | Ship | Bulk Carrier | 30,000 | 2 | 11 | 13 | 10 | 3 | 13 | 26 | 1.28 | 33 |
| 62 | Ship | General Cargo | 30,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 3 | 4 | 7 | 4 | 3 | 7 | 14 | 1.28 | 18 |
| 64 | Ship | Tanker | 25,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 65 | Ship | Bulk Carrier | 25,000 | 1 | 1 | 2 | 1 | 1 | 2 | 4 | 1.28 | 5 |
| 66 | Ship | General Cargo | 25,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 1 | 2 | 3 | 2 | 1 | 3 | 6 | 1.28 | 8 |
| 68 | Ship | Tanker | 20,000 | 10 | 4 | 14 | 4 | 9 | 13 | 27 | 1.64 | 44 |
| 69 | Ship | Bulk Carrier | 20,000 | 10 | 1 | 11 | 2 | 10 | 12 | 23 | 1.28 | 29 |
| 70 | Ship | General Cargo | 20,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 71 | Ship | Tanker | 15,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 72 | Ship | General Cargo | 15,000 | 1 | 2 | 3 | 1 | 1 | 2 | 5 | 1.28 | 6 |
| 73 | Ship | General Cargo | 10,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 74 | Ship | General Cargo | 5,000 | 3 | 0 | 3 | 2 | 0 | 2 | 5 | 1.28 | 6 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1.28 | 13 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 19 | 0 | 19 | 18 | 0 | 18 | 37 | 1.28 | 47 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 1.28 | 28 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 10 | 0 | 10 | 11 | 0 | 11 | 21 | 1.28 | 27 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 3 | 0 | 3 | 2 | 0 | 2 | 5 | 1.28 | 6 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| | | **Total Trips:** | | 255 | 312 | 567 | 433 | 133 | 566 | 1133 | | 1586 |

**Notes:**

[1] As part of the risk analysis, vessel trips will include future growth in the waterway that are projected to the mid-point of the remaining design life (assumed 50 years) of the structure. This equates to growth rates per year as follows for a 25-year projection. GF = (1+PERCENT/100)$^{25}$

- Aframax Tankers (DWT greater than 100,000 tonnes) = 9.735%
- All Other Tankers = 2.0%
- All Other Vessels = 1.0%

# VESSEL FLEET TRANSIT SPEEDS IN MAIN CHANNEL

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Transit Speeds (knots) | | | | Vessel Transit Speeds (m/sec) [1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | Outbound | | Inbound | | Outbound | |
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted |
| 1 | Ship | Bulk Carrier | 210,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 2 | Ship | Bulk Carrier | 205,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 3 | Ship | Bulk Carrier | 185,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 4 | Ship | Bulk Carrier | 180,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 5 | Ship | Bulk Carrier | 175,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 6 | Ship | Bulk Carrier | 170,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 7 | Ship | Bulk Carrier | 165,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 8 | Ship | Bulk Carrier | 155,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 9 | Ship | Bulk Carrier | 150,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 10 | Ship | Tanker | 120,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 11 | Ship | Bulk Carrier | 120,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 12 | Ship | Container | 120,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 13 | Ship | Tanker | 115,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 14 | Ship | Bulk Carrier | 115,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 15 | Ship | Container | 115,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 16 | Ship | Tanker | 110,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 17 | Ship | Bulk Carrier | 110,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 18 | Ship | Container | 110,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 19 | Ship | Tanker | 105,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 20 | Ship | Bulk Carrier | 105,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 21 | Ship | Container | 105,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 22 | Ship | Bulk Carrier | 100,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 23 | Ship | Container | 100,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 24 | Ship | Bulk Carrier | 95,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 25 | Ship | Container | 95,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 26 | Ship | Bulk Carrier | 90,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 27 | Ship | Bulk Carrier | 85,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 28 | Ship | Container | 85,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 29 | Ship | Bulk Carrier | 80,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 30 | Ship | Container | 80,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 31 | Ship | Tanker | 75,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 32 | Ship | Bulk Carrier | 75,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 33 | Ship | Container | 75,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 34 | Ship | Tanker | 70,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 35 | Ship | Bulk Carrier | 70,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 36 | Ship | Container | 70,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 37 | Ship | Tanker | 65,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 38 | Ship | Bulk Carrier | 65,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 39 | Ship | Container | 65,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 40 | Ship | Bulk Carrier | 60,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 41 | Ship | General Cargo | 60,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 42 | Ship | Container | 60,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 43 | Ship | Tanker | 55,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 44 | Ship | Bulk Carrier | 55,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 45 | Ship | General Cargo | 55,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 46 | Ship | Tanker | 50,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 47 | Ship | Bulk Carrier | 50,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 48 | Ship | General Cargo | 50,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 49 | Ship | Container | 50,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |

# VESSEL FLEET TRANSIT SPEEDS IN MAIN CHANNEL

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Transit Speeds (knots) | | | | Vessel Transit Speeds (m/sec) [1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | Outbound | | Inbound | | Outbound | |
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted |
| 50 | Ship | Tanker | 45,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 51 | Ship | Bulk Carrier | 45,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 52 | Ship | General Cargo | 45,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 53 | Ship | Tanker | 40,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 54 | Ship | Bulk Carrier | 40,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 55 | Ship | General Cargo | 40,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 56 | Ship | Tanker | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 57 | Ship | Bulk Carrier | 35,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 58 | Ship | General Cargo | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 59 | Ship | Container | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 60 | Ship | Tanker | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 61 | Ship | Bulk Carrier | 30,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 62 | Ship | General Cargo | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 64 | Ship | Tanker | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 65 | Ship | Bulk Carrier | 25,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 66 | Ship | General Cargo | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 68 | Ship | Tanker | 20,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 69 | Ship | Bulk Carrier | 20,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 70 | Ship | General Cargo | 20,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 71 | Ship | Tanker | 15,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 72 | Ship | General Cargo | 15,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 73 | Ship | General Cargo | 10,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 74 | Ship | General Cargo | 5,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |

**Notes:**

[1] Conversion (knot to m/sec) = 0.51 (convert vessel transit speeds from knots to meters/second for use in risk assessment equations)

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# ABERRANCY BASE RATE COMPUTATIONS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Code Recommended Aberrancy Base Rate, BR | Vessel Traffic Service, VTS | Electronic Chart Display & Information System, ECDIS | Other Navigation Aids | Port Control State, PCS | Pilotage 1 Pilot | Pilotage 2 Pilots (MRA-2) | | Daytime Only Transit Restrictions (MRA-2) | Visibility Restrictions (MRA-2) | Cruise Ship Considerations | Adjusted Aberrancy Base Rate, BR [1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Loaded | Ballasted | | | | Loaded | Ballasted |
| 1 | Ship | Bulk Carrier | 210,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 2 | Ship | Bulk Carrier | 205,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 3 | Ship | Bulk Carrier | 185,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 4 | Ship | Bulk Carrier | 180,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 5 | Ship | Bulk Carrier | 175,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 6 | Ship | Bulk Carrier | 170,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 7 | Ship | Bulk Carrier | 165,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 8 | Ship | Bulk Carrier | 155,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 9 | Ship | Bulk Carrier | 150,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 10 | Ship | Tanker | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 11 | Ship | Bulk Carrier | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 12 | Ship | Container | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 13 | Ship | Tanker | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 14 | Ship | Bulk Carrier | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 15 | Ship | Container | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 16 | Ship | Tanker | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 17 | Ship | Bulk Carrier | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 18 | Ship | Container | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 19 | Ship | Tanker | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 20 | Ship | Bulk Carrier | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 21 | Ship | Container | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 22 | Ship | Bulk Carrier | 100,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 23 | Ship | Container | 100,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 24 | Ship | Bulk Carrier | 95,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 25 | Ship | Container | 95,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 26 | Ship | Bulk Carrier | 90,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 27 | Ship | Bulk Carrier | 85,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 28 | Ship | Container | 85,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 29 | Ship | Bulk Carrier | 80,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 30 | Ship | Container | 80,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 31 | Ship | Tanker | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 32 | Ship | Bulk Carrier | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 33 | Ship | Container | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 34 | Ship | Tanker | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 35 | Ship | Bulk Carrier | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 36 | Ship | Container | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 37 | Ship | Tanker | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 38 | Ship | Bulk Carrier | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 39 | Ship | Container | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 40 | Ship | Bulk Carrier | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 41 | Ship | General Cargo | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 42 | Ship | Container | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 43 | Ship | Tanker | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 44 | Ship | Bulk Carrier | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 45 | Ship | General Cargo | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 46 | Ship | Tanker | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 47 | Ship | Bulk Carrier | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 48 | Ship | General Cargo | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 49 | Ship | Container | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |

# ABERRANCY BASE RATE COMPUTATIONS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Code Recommended Aberrancy Base Rate, BR | Vessel Traffic Service, VTS | Electronic Chart Display & Information System, ECDIS | Other Navigation Aids | Port Control State, PCS | Pilotage 1 Pilot | Pilotage 2 Pilots (MRA-2) | | Daytime Only Transit Restrictions (MRA-2) | Visibility Restrictions (MRA-2) | Cruise Ship Considerations | Adjusted Aberrancy Base Rate, BR [1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Loaded | Ballasted | | | | Loaded | Ballasted |
| 50 | Ship | Tanker | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 51 | Ship | Bulk Carrier | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 52 | Ship | General Cargo | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 53 | Ship | Tanker | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 54 | Ship | Bulk Carrier | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 55 | Ship | General Cargo | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 56 | Ship | Tanker | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 57 | Ship | Bulk Carrier | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 58 | Ship | General Cargo | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 59 | Ship | Container | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 60 | Ship | Tanker | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 61 | Ship | Bulk Carrier | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 62 | Ship | General Cargo | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 64 | Ship | Tanker | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 65 | Ship | Bulk Carrier | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 66 | Ship | General Cargo | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 68 | Ship | Tanker | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 69 | Ship | Bulk Carrier | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 70 | Ship | General Cargo | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 71 | Ship | Tanker | 15,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 72 | Ship | General Cargo | 15,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 73 | Ship | General Cargo | 10,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 74 | Ship | General Cargo | 5,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |

**Notes:**

[1] Adjustments to the aberrancy Base Rate (BR) due to waterway current restrictions are accounted for elsewhere in the vessel collision risk analysis (refer to correction factors $R_C$ and $R_{XC}$ for the Probability of Aberrancy at each transit leg).

# MISCELLANEOUS INFORMATION

## CHANNEL CHARACTERISTICS

| | | |
|---|---|---|
| Waterway Current Speed ($V_{min}$) = | **2.57** | m/sec |
| Water Elevation = | **1.60** | m (based on Chart Datum) |
| Sea Level Rise Adjustment = | **0.10** | m |
| Soft Soil Allowance = | **2.00** | m (assumed depth that vessels can "plow" through soft bottom material or "ride up" on underlying rock) |

## AVAILABLE WATER DEPTH AT PIERS

| Pier ID | Description | Mudline Elevation (m) [1] | | Water Elevation (m) | Soft Soil Allowance (m) | Design Water Depth (m) | |
|---|---|---|---|---|---|---|---|
| | | Inbound | Outbound | | | Inbound | Outbound |
| **1** | **North Tower** | **5.00** | **5.00** | 1.70 | 2.00 | -1.30 | -1.30 |
| **2** | **South Tower** | **-7.00** | **-7.00** | 1.70 | 2.00 | 10.70 | 10.70 |

**Notes:**

[1] Mudline elevation is based on Chart Datum (CD) and was obtained from Nautical Chart 3493

## PROBABILITY OF ABERRANCY VARIABLES FOR EACH VESSEL TRANSIT PATH

| Leg ID | Waterway Region for Bridge Location | Angle of Channel Turn, θ (deg) [1] | Correction Factor, $R_B$ | Current Angle to Vessel Path (deg) [2] | Parallel Current, $V_C$ (m/sec) | Perpendicular Current, $V_{XC}$ (m/sec) | Correction Factor, $R_C$ | Correction Factor, $R_{XC}$ | Vessel Traffic Density | Correction Factor, $R_D$ | Summation ($R_B$*$R_C$*$R_{XC}$*$R_D$) | Aberrancy Distribution [3] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Inbound | Outbound |
| **1** | **Transition** | **44.4795** | 1.4942 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 2.2622 | **0.16** | **N/A** |
| **2** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.40** | **N/A** |
| **3** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.22** | **N/A** |
| **4** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.22** | **N/A** |
| **5** | **Transition** | **28.0177** | 1.3113 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 1.9853 | **N/A** | **0.50** |
| **6** | **Straight** | **0.0000** | 1.0000 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 1.5140 | **N/A** | **0.50** |

**Notes:**

[1] Angle of the turn region in accordance with information shown on Nautical Chart 3493, AIS transit data near the bridge, and CAN/CSA S6-14 Figure A3.3.1

[2] The angle between the water current direction and each channel transition leg

[3] Distribution of the Probability of Aberrancy for each channel transition leg is established as a ratio of the length of each leg to the overall length being considered (approximately 1 nautical mile or 2000m)

## GEOMETRIC PROBABILITY DISTANCES FOR NORMAL DISTRIBUTION

| Pier ID | Description | Leg 1 [1] | | | Leg 2 [1] | | | Leg 3 [1] | | | Leg 4 [1] | | | Leg 5 [1] | | | Leg 6 [1] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) |
| 1 | North Tower | **328.75** | 342.54 | **356.34** | **32.88** | 44.83 | **56.78** | **138.33** | 149.19 | **160.06** | **245.78** | 254.19 | **262.59** | **212.19** | 219.89 | **227.60** | **212.19** | 219.89 | **227.60** |
| 2 | South Tower | **684.04** | 701.58 | **719.11** | **356.33** | 371.76 | **387.18** | **274.04** | 288.34 | **302.64** | **197.61** | 209.61 | **221.61** | **239.38** | 250.07 | **260.76** | **239.38** | 250.07 | **260.76** |

**Notes:**

[1] Perpendicular distances at each channel transition leg from the centerline of vessel transit path to the bridge element being considered. Distance "x" is from the centerline of vessel transit path to the centerline of bridge element. Distance "$x_1$" (scaled from CADD drawing) is from the centerline of vessel transit path to the closest edge of the bridge element. Distance "$x_2$" (scaled from CADD drawing) is from the centerline of vessel transit path to the farthest edge of the bridge element.

## PROTECTION FACTOR

| Pier ID | Description | Leg 1 | | Leg 2 | | Leg 3 | | Leg 4 | | Leg 5 | | Leg 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound |
| 1 | North Tower | **0.62** | **N/A** | **0.54** | **N/A** | **0.43** | **N/A** | **0.33** | **N/A** | **N/A** | **0.18** | **N/A** | **0.18** |
| 2 | South Tower | **0.003** | **N/A** | **0.01** | **N/A** | **0.02** | **N/A** | **0.04** | **N/A** | **N/A** | **0.14** | **N/A** | **0.14** |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053804 | 0.053804 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053804 | 0.053804 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049883 | 0.049883 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049883 | 0.049883 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049686 | 0.049686 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048933 | 0.048933 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048933 | 0.048933 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049023 | 0.049023 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046613 | 0.046613 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000027 | 0.044813 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044769 | 0.044769 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053234 | 0.053234 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000027 | 0.044813 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044769 | 0.044769 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.052415 | 0.052415 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000023 | 0.043133 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044909 | 0.044909 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049831 | 0.049831 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000023 | 0.042606 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.041590 | 0.041590 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049838 | 0.049838 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.038622 | 0.038622 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.051971 | 0.051971 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.037482 | 0.037482 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.051743 | 0.051743 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.037482 | 0.037482 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.034028 | 0.034028 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046859 | 0.046859 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.033282 | 0.033282 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048248 | 0.048248 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000014 | 0.034704 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.033282 | 0.033282 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046498 | 0.046498 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000013 | 0.033846 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.029214 | 0.029214 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.045990 | 0.045990 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000010 | 0.031005 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027612 | 0.027612 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044626 | 0.044626 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.024857 | 0.024857 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.028082 | 0.028082 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.041220 | 0.041220 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.023082 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.024857 | 0.024857 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027612 | 0.027612 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.022778 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.025429 | 0.025429 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027142 | 0.027142 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.038337 | 0.038337 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.022163 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.023031 | 0.023031 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.022751 | 0.022751 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000004 | 0.020063 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.017939 | 0.017939 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.020355 | 0.020355 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.028844 | 0.028844 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.013690 | 0.013690 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.017043 | 0.017043 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.015832 | 0.015832 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.025304 | 0.025304 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.009200 | 0.009200 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011929 | 0.011929 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011929 | 0.011929 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.019930 | 0.019930 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.008924 | 0.008924 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.008474 | 0.008474 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.013763 | 0.013763 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.004079 | 0.004079 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006623 | 0.006623 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002272 | 0.002272 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002350 | 0.002350 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.045210 | 0.045210 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.043545 | 0.043545 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.041184 | 0.041184 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.040685 | 0.040685 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.035982 | 0.035982 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.031633 | 0.031633 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.020774 | 0.020774 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.007148 | 0.007148 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000709 | 0.000709 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] $PA = (BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096934 | 0.096934 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096934 | 0.096934 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092813 | 0.092813 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092813 | 0.092813 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.093749 | 0.093749 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092706 | 0.092706 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092706 | 0.092706 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100503 | 0.100503 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.097595 | 0.097595 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.293189 | 0.106299 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.103154 | 0.103154 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.087504 | 0.087504 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.293189 | 0.106299 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.103154 | 0.103154 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.094323 | 0.094323 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.294705 | 0.110550 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.102764 | 0.102764 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.079055 | 0.079055 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.285780 | 0.105624 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.111152 | 0.111152 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.078824 | 0.078824 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.102892 | 0.102892 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.081631 | 0.081631 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.105471 | 0.105471 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086118 | 0.086118 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.105471 | 0.105471 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.095298 | 0.095298 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.083869 | 0.083869 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096918 | 0.096918 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086484 | 0.086484 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.252373 | 0.098253 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096918 | 0.096918 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.085819 | 0.085819 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.245976 | 0.095698 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.116646 | 0.116646 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.088159 | 0.088159 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.248120 | 0.101661 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108392 | 0.108392 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.085410 | 0.085410 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.113752 | 0.113752 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.110319 | 0.110319 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086283 | 0.086283 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.253671 | 0.117220 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.113752 | 0.113752 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108392 | 0.108392 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.253883 | 0.117818 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.112639 | 0.112639 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.106464 | 0.106464 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.084655 | 0.084655 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.254313 | 0.119031 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108759 | 0.108759 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.109304 | 0.109304 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.237028 | 0.111720 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.113108 | 0.113108 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.111142 | 0.111142 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100269 | 0.100269 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.122241 | 0.122241 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.114954 | 0.114954 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.117506 | 0.117506 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086168 | 0.086168 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.124339 | 0.124339 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123397 | 0.123397 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123397 | 0.123397 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100539 | 0.100539 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.125108 | 0.125108 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123280 | 0.123280 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.116137 | 0.116137 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.128994 | 0.128994 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.122630 | 0.122630 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.124977 | 0.124977 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.138383 | 0.138383 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.075464 | 0.075464 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.081411 | 0.081411 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.075076 | 0.075076 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.077380 | 0.077380 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.091430 | 0.091430 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.096904 | 0.096904 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.101180 | 0.101180 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.111543 | 0.111543 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.137764 | 0.137764 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084140 | 0.084140 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084140 | 0.084140 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079884 | 0.079884 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079884 | 0.079884 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.080492 | 0.080492 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079490 | 0.079490 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079490 | 0.079490 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085092 | 0.085092 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082175 | 0.082175 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.054561 | 0.087617 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085406 | 0.085406 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077104 | 0.077104 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.054561 | 0.087617 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085406 | 0.085406 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081802 | 0.081802 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.053453 | 0.089890 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085187 | 0.085187 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069887 | 0.069887 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.052013 | 0.086279 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.089661 | 0.089661 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069720 | 0.069720 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082758 | 0.082758 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072423 | 0.072423 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084021 | 0.084021 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075631 | 0.075631 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084021 | 0.084021 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075604 | 0.075604 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072444 | 0.072444 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076364 | 0.076364 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074784 | 0.074784 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.042584 | 0.077904 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076364 | 0.076364 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.073729 | 0.073729 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.041288 | 0.075794 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.087244 | 0.087244 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075238 | 0.075238 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.039718 | 0.078448 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081036 | 0.081036 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072807 | 0.072807 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082780 | 0.082780 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082540 | 0.082540 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072232 | 0.072232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035639 | 0.083755 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082780 | 0.082780 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081036 | 0.081036 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035483 | 0.083911 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082441 | 0.082441 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079531 | 0.079531 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.070024 | 0.070024 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)



# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035166 | 0.084216 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078482 | 0.078482 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078636 | 0.078636 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.031893 | 0.078233 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.077409 | 0.077409 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078098 | 0.078098 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076437 | 0.076437 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.078688 | 0.078688 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077743 | 0.077743 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078142 | 0.078142 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065371 | 0.065371 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.074144 | 0.074144 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077314 | 0.077314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077314 | 0.077314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.071308 | 0.071308 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.074122 | 0.074122 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072472 | 0.072472 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075334 | 0.075334 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.065858 | 0.065858 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068904 | 0.068904 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057501 | 0.057501 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.063314 | 0.063314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.065831 | 0.065831 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.069576 | 0.069576 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.064239 | 0.064239 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.065719 | 0.065719 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.073799 | 0.073799 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.075591 | 0.075591 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.072279 | 0.072279 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.064298 | 0.064298 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.050670 | 0.050670 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062009 | 0.062009 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062009 | 0.062009 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057783 | 0.057783 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057783 | 0.057783 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057925 | 0.057925 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057033 | 0.057033 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057033 | 0.057033 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059479 | 0.059479 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056742 | 0.056742 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001520 | 0.057871 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056930 | 0.056930 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058620 | 0.058620 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001520 | 0.057871 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056930 | 0.056930 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060154 | 0.060154 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001408 | 0.057703 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056929 | 0.056929 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053443 | 0.053443 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001384 | 0.055894 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056588 | 0.056588 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053375 | 0.053375 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051853 | 0.051853 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055835 | 0.055835 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051593 | 0.051593 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057080 | 0.057080 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051593 | 0.051593 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045939 | 0.045939 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.052735 | 0.052735 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045739 | 0.045739 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.054590 | 0.054590 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000971 | 0.047305 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045739 | 0.045739 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053068 | 0.053068 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000932 | 0.045893 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.046908 | 0.046908 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053404 | 0.053404 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000810 | 0.044976 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043476 | 0.043476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051525 | 0.051525 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.041967 | 0.041967 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.044369 | 0.044369 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.049174 | 0.049174 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000549 | 0.040860 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.041967 | 0.041967 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043476 | 0.043476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000540 | 0.040660 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042301 | 0.042301 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042582 | 0.042582 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.046440 | 0.046440 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000523 | 0.040245 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.039047 | 0.039047 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038876 | 0.038876 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000449 | 0.036530 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.034430 | 0.034430 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.036732 | 0.036732 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042687 | 0.042687 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.030775 | 0.030775 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.033728 | 0.033728 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.032723 | 0.032723 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.036007 | 0.036007 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.024656 | 0.024656 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028555 | 0.028555 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028555 | 0.028555 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.034135 | 0.034135 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.024316 | 0.024316 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.023377 | 0.023377 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.029913 | 0.029913 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.015764 | 0.015764 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.020188 | 0.020188 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.011026 | 0.011026 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.012031 | 0.012031 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.048882 | 0.048882 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.049476 | 0.049476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.045738 | 0.045738 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.046068 | 0.046068 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.046500 | 0.046500 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.044314 | 0.044314 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.035138 | 0.035138 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.019839 | 0.019839 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.006060 | 0.006060 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062377 | 0.062377 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064824 | 0.064824 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061974 | 0.061974 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061956 | 0.061956 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064396 | 0.064396 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005333 | 0.064870 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062964 | 0.062964 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056126 | 0.056126 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005213 | 0.062504 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063975 | 0.063975 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056031 | 0.056031 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058501 | 0.058501 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058605 | 0.058605 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.060404 | 0.060404 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052072 | 0.052072 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056283 | 0.056283 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058312 | 0.058312 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003846 | 0.053737 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056884 | 0.056884 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003700 | 0.052089 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.055998 | 0.055998 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057551 | 0.057551 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003341 | 0.052129 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.055476 | 0.055476 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052781 | 0.052781 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.053560 | 0.053560 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002517 | 0.050382 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002488 | 0.050266 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051160 | 0.051160 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050598 | 0.050598 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050901 | 0.050901 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002431 | 0.050018 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047584 | 0.047584 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047491 | 0.047491 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002121 | 0.045543 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.043662 | 0.043662 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.045667 | 0.045667 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.049839 | 0.049839 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.040997 | 0.040997 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.043182 | 0.043182 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.042467 | 0.042467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.041733 | 0.041733 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.034767 | 0.034767 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.041865 | 0.041865 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.034467 | 0.034467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033286 | 0.033286 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.039483 | 0.039483 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.025001 | 0.025001 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.029700 | 0.029700 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.018840 | 0.018840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.020840 | 0.020840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051602 | 0.051602 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.053055 | 0.053055 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.048796 | 0.048796 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.049443 | 0.049443 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051992 | 0.051992 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.050842 | 0.050842 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.042904 | 0.042904 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.028412 | 0.028412 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.012379 | 0.012379 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062377 | 0.062377 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064824 | 0.064824 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061974 | 0.061974 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061956 | 0.061956 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064396 | 0.064396 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005333 | 0.064870 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062964 | 0.062964 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056126 | 0.056126 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005213 | 0.062504 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063975 | 0.063975 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056031 | 0.056031 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058501 | 0.058501 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058605 | 0.058605 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.060404 | 0.060404 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052072 | 0.052072 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056283 | 0.056283 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058312 | 0.058312 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003846 | 0.053737 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056884 | 0.056884 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003700 | 0.052089 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.055998 | 0.055998 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057551 | 0.057551 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003341 | 0.052129 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.055476 | 0.055476 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052781 | 0.052781 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.053560 | 0.053560 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002517 | 0.050382 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002488 | 0.050266 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051160 | 0.051160 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050598 | 0.050598 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050901 | 0.050901 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002431 | 0.050018 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047584 | 0.047584 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047491 | 0.047491 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002121 | 0.045543 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.043662 | 0.043662 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.045667 | 0.045667 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.049839 | 0.049839 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.040997 | 0.040997 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.043182 | 0.043182 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.042467 | 0.042467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.041733 | 0.041733 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.034767 | 0.034767 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.041865 | 0.041865 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.034467 | 0.034467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033286 | 0.033286 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.039483 | 0.039483 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.025001 | 0.025001 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.029700 | 0.029700 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.018840 | 0.018840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.020840 | 0.020840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051602 | 0.051602 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.053055 | 0.053055 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.048796 | 0.048796 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.049443 | 0.049443 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051992 | 0.051992 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.050842 | 0.050842 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.042904 | 0.042904 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.028412 | 0.028412 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.012379 | 0.012379 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 2.8765 | 0.00 | 371.46 | 0.00 | 156.93 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.007454 | 0.007454 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 2.8765 | 0.00 | 442.03 | 0.00 | 155.05 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.007454 | 0.007454 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 2.8440 | 0.00 | 397.04 | 0.00 | 145.63 | 0 | 3 | 1.28 | 0.000013 | 0.000013 | 0.006193 | 0.006193 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 2.8440 | 0.00 | 411.83 | 0.00 | 143.65 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.006193 | 0.006193 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 2.8328 | 0.00 | 336.07 | 0.00 | 141.08 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.005895 | 0.005895 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 2.8290 | 0.00 | 369.79 | 0.00 | 138.86 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.005722 | 0.005722 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 2.8290 | 0.00 | 362.06 | 0.00 | 136.80 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005722 | 0.005722 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 2.8912 | 0.00 | 351.60 | 0.00 | 135.51 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.004450 | 0.004450 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 2.8592 | 0.00 | 346.44 | 0.00 | 131.83 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.003938 | 0.003938 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 2.6778 | 0.00 | 206.64 | 0.00 | 110.43 | 0 | 3 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002530 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 2.7463 | 0.00 | 197.98 | 0.00 | 113.26 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.002774 | 0.002774 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.009908 | 0.009908 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 2.6778 | 0.00 | 251.06 | 0.00 | 108.11 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002530 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 2.7463 | 0.00 | 215.09 | 0.00 | 110.87 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.002774 | 0.002774 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.007274 | 0.007274 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 2.6129 | 0.00 | 192.30 | 0.00 | 103.17 | 0 | 2 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.001896 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 2.7543 | 0.00 | 220.72 | 0.00 | 108.75 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.002845 | 0.002845 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.010348 | 0.010348 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 2.6396 | 0.00 | 193.21 | 0.00 | 101.82 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002080 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 2.5809 | 0.00 | 185.69 | 0.00 | 99.56 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.001594 | 0.001594 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.010453 | 0.010453 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 2.5809 | 0.00 | 151.80 | 0.00 | 97.16 | 0 | 2 | 1.28 | 0.000013 | 0.000013 | 0.001485 | 0.001485 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011186 | 0.011186 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 2.5700 | 0.00 | 176.91 | 0.00 | 94.30 | 0 | 5 | 1.28 | 0.000013 | 0.000013 | 0.001208 | 0.001208 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.009230 | 0.009230 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 2.5700 | 0.00 | 164.74 | 0.00 | 91.79 | 0 | 4 | 1.28 | 0.000013 | 0.000013 | 0.001208 | 0.001208 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 2.5700 | 0.00 | 132.88 | 0.00 | 89.20 | 0 | 39 | 1.28 | 0.000013 | 0.000013 | 0.001102 | 0.001102 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006557 | 0.006557 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 2.5700 | 0.00 | 120.71 | 0.00 | 86.54 | 0 | 33 | 1.28 | 0.000013 | 0.000013 | 0.000950 | 0.000950 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006735 | 0.006735 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 2.5700 | 0.00 | 137.21 | 0.00 | 83.79 | 0 | 2 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.001088 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 2.5700 | 0.00 | 121.99 | 0.00 | 83.79 | 0 | 13 | 1.28 | 0.000013 | 0.000013 | 0.000950 | 0.000950 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005889 | 0.005889 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 2.5700 | 0.00 | 113.98 | 0.00 | 80.95 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.001063 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 2.5700 | 0.00 | 99.62 | 0.00 | 80.95 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000302 | 0.000302 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005151 | 0.005151 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 2.5700 | 0.00 | 109.78 | 0.00 | 78.00 | 0 | 1 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000603 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 2.5700 | 0.00 | 101.84 | 0.00 | 78.00 | 0 | 35 | 1.28 | 0.000013 | 0.000013 | 0.000300 | 0.000300 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005010 | 0.005010 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 2.5700 | 0.00 | 95.64 | 0.00 | 74.94 | 0 | 44 | 1.28 | 0.000013 | 0.000013 | 0.000164 | 0.000164 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000305 | 0.000305 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.003446 | 0.003446 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 2.5700 | 0.00 | 109.12 | 0.00 | 71.75 | 0 | 2 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000109 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 2.5700 | 0.00 | 93.69 | 0.00 | 71.75 | 0 | 8 | 1.28 | 0.000013 | 0.000013 | 0.000164 | 0.000164 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 2.5700 | 2.5700 | 136.55 | 136.55 | 71.75 | 71.75 | 3 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000300 | 0.000300 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 2.5700 | 196.08 | 107.22 | 68.41 | 68.41 | 3 | 8 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000101 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 2.5700 | 2.5700 | 197.36 | 99.31 | 68.41 | 68.41 | 2 | 3 | 1.28 | 0.000013 | 0.000013 | 0.000187 | 0.000187 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000295 | 0.000295 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002682 | 0.002682 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 2.5700 | 187.17 | 114.54 | 64.90 | 64.90 | 0 | 1 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000087 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 2.5700 | 2.5700 | 177.84 | 81.21 | 64.90 | 64.90 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.000137 | 0.000137 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 2.5700 | 2.5700 | 155.50 | 155.50 | 64.90 | 64.90 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000128 | 0.000128 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 2.5700 | 158.64 | 82.46 | 61.19 | 61.19 | 0 | 4 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000070 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 2.5700 | 2.5700 | 162.27 | 76.43 | 61.19 | 61.19 | 6 | 20 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 2.5700 | 2.5700 | 146.06 | 146.06 | 61.19 | 61.19 | 2 | 7 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 2.5700 | 2.5700 | 146.96 | 73.82 | 57.24 | 57.24 | 1 | 2 | 1.64 | 0.000013 | 0.000013 | 0.000042 | 0.000042 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 2.5700 | 2.5700 | 153.53 | 72.89 | 57.24 | 57.24 | 6 | 12 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 2.5700 | 2.5700 | 80.62 | 80.62 | 57.24 | 57.24 | 5 | 12 | 1.28 | 0.000013 | 0.000013 | 0.000075 | 0.000075 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 2.5700 | 2.5700 | 139.94 | 139.94 | 57.24 | 57.24 | 6 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000462 | 0.000462 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 2.5700 | 2.5700 | 117.34 | 59.36 | 52.99 | 52.99 | 1 | 7 | 1.64 | 0.000013 | 0.000013 | 0.000010 | 0.000010 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 2.5700 | 2.5700 | 135.88 | 55.03 | 52.99 | 52.99 | 2 | 11 | 1.28 | 0.000013 | 0.000013 | 0.000032 | 0.000032 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 2.5700 | 2.5700 | 123.65 | 123.65 | 52.99 | 52.99 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000022 | 0.000022 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 2.5700 | 2.5700 | 131.33 | 60.54 | 52.99 | 52.99 | 3 | 4 | 1.28 | 0.000013 | 0.000013 | 0.000426 | 0.000426 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 2.5700 | 2.5700 | 92.43 | 47.64 | 48.38 | 48.38 | 0 | 1 | 1.64 | 0.000013 | 0.000013 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 2.5700 | 2.5700 | 83.95 | 59.05 | 48.38 | 48.38 | 1 | 1 | 1.28 | 0.000013 | 0.000013 | 0.000006 | 0.000006 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 2.5700 | 2.5700 | 83.35 | 83.35 | 48.38 | 48.38 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000006 | 0.000006 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 2.5700 | 2.5700 | 99.55 | 54.51 | 48.38 | 48.38 | 1 | 2 | 1.28 | 0.000013 | 0.000013 | 0.000094 | 0.000094 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 2.5700 | 2.5700 | 81.72 | 42.44 | 43.27 | 43.27 | 10 | 4 | 1.64 | 0.000013 | 0.000013 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 2.5700 | 2.5700 | 68.58 | 43.17 | 43.27 | 43.27 | 10 | 1 | 1.28 | 0.000013 | 0.000013 | 0.000001 | 0.000001 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 2.5700 | 2.5700 | 88.91 | 88.91 | 43.27 | 43.27 | 2 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000012 | 0.000012 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 2.5700 | 2.5700 | 53.74 | 33.01 | 37.47 | 37.47 | 0 | 1 | 1.64 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 2.5700 | 2.5700 | 49.22 | 49.22 | 37.47 | 37.47 | 1 | 2 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 2.5700 | 2.5700 | 20.15 | 20.15 | 30.60 | 30.60 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 2.5700 | 2.5700 | 26.84 | 26.84 | 21.63 | 21.63 | 3 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 3.2827 | 3.2827 | 382.31 | 382.31 | 96.84 | 96.84 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.007896 | 0.007896 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 3.0989 | 3.0989 | 301.72 | 301.72 | 85.47 | 85.47 | 5 | 0 | 1.28 | 0.000002 | 0.000002 | 0.005259 | 0.005259 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 3.1338 | 3.1338 | 285.32 | 285.32 | 82.86 | 82.86 | 19 | 0 | 1.28 | 0.000002 | 0.000002 | 0.005365 | 0.005365 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 3.0659 | 3.0659 | 236.54 | 236.54 | 76.99 | 76.99 | 11 | 0 | 1.28 | 0.000002 | 0.000002 | 0.004619 | 0.004619 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 2.6414 | 2.6414 | 139.61 | 139.61 | 58.93 | 58.93 | 10 | 0 | 1.28 | 0.000002 | 0.000002 | 0.001598 | 0.001598 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 2.5700 | 2.5700 | 106.76 | 106.76 | 52.33 | 52.33 | 3 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000765 | 0.000765 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 2.5700 | 2.5700 | 54.82 | 54.82 | 38.47 | 38.47 | 3 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000111 | 0.000111 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 2.5700 | 2.5700 | 24.45 | 24.45 | 25.69 | 25.69 | 1 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000001 | 0.000001 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.5700 | 2.5700 | 12.69 | 12.69 | 18.51 | 18.51 | 1 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.3860 | 0.00 | 514.69 | 0.00 | 184.72 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.049977 | 0.049977 | 0.000000 | 0.007050 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.3860 | 0.00 | 612.48 | 0.00 | 182.51 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.049977 | 0.049977 | 0.000000 | 0.005789 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.3622 | 0.00 | 554.91 | 0.00 | 172.16 | 0 | 3 | 1.28 | 0.000044 | 0.000044 | 0.046166 | 0.046166 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 3.3622 | 0.00 | 575.58 | 0.00 | 169.82 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.046166 | 0.046166 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 3.3567 | 0.00 | 471.88 | 0.00 | 167.17 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.045869 | 0.045869 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.3549 | 0.00 | 520.04 | 0.00 | 164.67 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.045161 | 0.045161 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.3549 | 0.00 | 509.17 | 0.00 | 162.23 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.045161 | 0.045161 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 3.7935 | 0.00 | 605.30 | 0.00 | 177.80 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.044565 | 0.044565 | 0.000000 | 0.002999 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 3.7639 | 0.00 | 600.36 | 0.00 | 173.54 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.042274 | 0.042274 | 0.000000 | 0.000346 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 3.4123 | 0.00 | 335.55 | 0.00 | 140.72 | 0 | 3 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.039720 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 3.7087 | 0.00 | 361.05 | 0.00 | 152.94 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.039908 | 0.039908 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.050313 | 0.050313 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 3.4123 | 0.00 | 407.68 | 0.00 | 137.76 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.039720 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 3.7087 | 0.00 | 392.24 | 0.00 | 149.72 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.039908 | 0.039908 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.048737 | 0.048737 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 3.3806 | 0.00 | 321.89 | 0.00 | 133.48 | 0 | 2 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.037704 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 3.7126 | 0.00 | 401.02 | 0.00 | 146.59 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.040083 | 0.040083 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.047508 | 0.047508 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.3936 | 0.00 | 319.36 | 0.00 | 130.91 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.037502 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 3.6277 | 0.00 | 366.88 | 0.00 | 139.94 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.036099 | 0.036099 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.047541 | 0.047541 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 3.6277 | 0.00 | 299.93 | 0.00 | 136.57 | 0 | 2 | 1.28 | 0.000044 | 0.000044 | 0.033629 | 0.033629 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.049568 | 0.049568 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 3.5991 | 0.00 | 346.97 | 0.00 | 132.06 | 0 | 5 | 1.28 | 0.000044 | 0.000044 | 0.032317 | 0.032317 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.048837 | 0.048837 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 3.5991 | 0.00 | 323.10 | 0.00 | 128.54 | 0 | 4 | 1.28 | 0.000044 | 0.000044 | 0.032317 | 0.032317 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 3.5991 | 0.00 | 260.61 | 0.00 | 124.92 | 0 | 39 | 1.28 | 0.000044 | 0.000044 | 0.029471 | 0.029471 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.043780 | 0.043780 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 3.5792 | 0.00 | 234.11 | 0.00 | 120.52 | 0 | 33 | 1.28 | 0.000044 | 0.000044 | 0.028624 | 0.028624 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.045019 | 0.045019 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 3.5942 | 0.00 | 268.37 | 0.00 | 117.18 | 0 | 2 | 1.64 | 0.000024 | 0.000044 | 0.000003 | 0.029969 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 3.5792 | 0.00 | 236.60 | 0.00 | 116.69 | 0 | 13 | 1.28 | 0.000044 | 0.000044 | 0.028624 | 0.028624 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.043203 | 0.043203 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 3.5942 | 0.00 | 222.93 | 0.00 | 113.21 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.000002 | 0.029263 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 3.4277 | 0.00 | 177.21 | 0.00 | 107.96 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.023684 | 0.023684 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.042440 | 0.042440 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 3.5200 | 0.00 | 205.95 | 0.00 | 106.84 | 0 | 1 | 1.64 | 0.000024 | 0.000044 | 0.000002 | 0.026103 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 3.4343 | 0.00 | 181.86 | 0.00 | 104.24 | 0 | 35 | 1.28 | 0.000044 | 0.000044 | 0.022509 | 0.022509 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.041238 | 0.041238 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 3.3645 | 0.00 | 163.91 | 0.00 | 98.11 | 0 | 44 | 1.28 | 0.000044 | 0.000044 | 0.019714 | 0.019714 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.022874 | 0.022874 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.037547 | 0.037547 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 3.3186 | 0.00 | 181.95 | 0.00 | 92.65 | 0 | 2 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017968 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 3.1661 | 0.00 | 142.20 | 0.00 | 88.39 | 0 | 8 | 1.28 | 0.000044 | 0.000044 | 0.019714 | 0.019714 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 3.4343 | 3.4343 | 243.83 | 243.83 | 95.88 | 95.88 | 3 | 0 | 1.28 | 0.000044 | 0.000044 | 0.022509 | 0.022509 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 3.3106 | 196.08 | 177.92 | 68.41 | 88.13 | 3 | 8 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017673 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 3.1770 | 3.1770 | 301.61 | 151.77 | 84.57 | 84.57 | 2 | 3 | 1.28 | 0.000044 | 0.000044 | 0.020286 | 0.020286 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.022144 | 0.022144 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.034653 | 0.034653 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 3.2943 | 187.17 | 188.20 | 64.90 | 83.19 | 0 | 1 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017081 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 3.1549 | 3.1549 | 267.99 | 122.38 | 79.67 | 79.67 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.018201 | 0.018201 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 3.3420 | 3.3420 | 262.95 | 262.95 | 84.40 | 84.40 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.017924 | 0.017924 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 3.2777 | 158.64 | 134.12 | 61.19 | 78.04 | 0 | 4 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.015406 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 3.1072 | 3.1072 | 237.21 | 111.72 | 73.98 | 73.98 | 6 | 20 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 3.2861 | 3.2861 | 238.79 | 238.79 | 78.24 | 78.24 | 2 | 7 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 3.2251 | 3.2251 | 231.43 | 116.26 | 71.83 | 71.83 | 1 | 2 | 1.64 | 0.000044 | 0.000044 | 0.013483 | 0.013483 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 3.1072 | 3.1072 | 224.43 | 106.55 | 69.20 | 69.20 | 6 | 12 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.2861 | 3.2861 | 131.81 | 131.81 | 73.19 | 73.19 | 5 | 12 | 1.28 | 0.000044 | 0.000044 | 0.015685 | 0.015685 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 3.4908 | 3.4908 | 258.19 | 258.19 | 77.75 | 77.75 | 6 | 0 | 1.28 | 0.000044 | 0.000044 | 0.024064 | 0.024064 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 3.0850 | 3.0850 | 169.07 | 85.54 | 63.61 | 63.61 | 1 | 7 | 1.64 | 0.000044 | 0.000044 | 0.009669 | 0.009669 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 3.0406 | 3.0406 | 190.21 | 77.03 | 62.70 | 62.70 | 2 | 11 | 1.28 | 0.000044 | 0.000044 | 0.012655 | 0.012655 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 3.1584 | 3.1584 | 186.74 | 186.74 | 65.12 | 65.12 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.011557 | 0.011557 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 3.4968 | 3.4968 | 243.13 | 112.08 | 72.10 | 72.10 | 3 | 4 | 1.28 | 0.000044 | 0.000044 | 0.021316 | 0.021316 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 2.9272 | 2.9272 | 119.91 | 61.81 | 55.10 | 55.10 | 0 | 1 | 1.64 | 0.000044 | 0.000044 | 0.006050 | 0.006050 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 2.9135 | 2.9135 | 107.89 | 75.90 | 54.84 | 54.84 | 1 | 1 | 1.28 | 0.000044 | 0.000044 | 0.008214 | 0.008214 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.0279 | 3.0279 | 115.70 | 115.70 | 56.99 | 56.99 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.008214 | 0.008214 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.3186 | 3.3186 | 165.99 | 90.89 | 62.47 | 62.47 | 1 | 2 | 1.28 | 0.000044 | 0.000044 | 0.015626 | 0.015626 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 2.9138 | 2.9138 | 105.04 | 54.56 | 49.06 | 49.06 | 10 | 4 | 1.64 | 0.000044 | 0.000044 | 0.005830 | 0.005830 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 2.8176 | 2.8176 | 82.43 | 51.89 | 47.44 | 47.44 | 10 | 1 | 1.28 | 0.000044 | 0.000044 | 0.005504 | 0.005504 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.1067 | 3.1067 | 129.93 | 129.93 | 52.30 | 52.30 | 2 | 0 | 1.28 | 0.000044 | 0.000044 | 0.009835 | 0.009835 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 2.6286 | 2.6286 | 56.22 | 34.53 | 38.33 | 38.33 | 0 | 1 | 1.64 | 0.000044 | 0.000044 | 0.002314 | 0.002314 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 2.8131 | 2.8131 | 58.97 | 58.97 | 41.02 | 41.02 | 1 | 2 | 1.28 | 0.000044 | 0.000044 | 0.004128 | 0.004128 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 2.5700 | 2.5700 | 20.15 | 20.15 | 30.60 | 30.60 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.001174 | 0.001174 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 2.5700 | 2.5700 | 26.84 | 26.84 | 21.63 | 21.63 | 3 | 0 | 1.28 | 0.000044 | 0.000044 | 0.001195 | 0.001195 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.2229 | 4.2229 | 632.67 | 632.67 | 124.58 | 124.58 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.042850 | 0.042850 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.1439 | 4.1439 | 539.53 | 539.53 | 114.30 | 114.30 | 5 | 0 | 1.28 | 0.000007 | 0.000007 | 0.040455 | 0.040455 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.1610 | 4.1610 | 503.02 | 503.02 | 110.02 | 110.02 | 19 | 0 | 1.28 | 0.000007 | 0.000007 | 0.038529 | 0.038529 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.1278 | 4.1278 | 428.77 | 428.77 | 103.65 | 103.65 | 11 | 0 | 1.28 | 0.000007 | 0.000007 | 0.037773 | 0.037773 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 3.9202 | 3.9202 | 307.51 | 307.51 | 87.46 | 87.46 | 10 | 0 | 1.28 | 0.000007 | 0.000007 | 0.031709 | 0.031709 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 3.7986 | 3.7986 | 233.23 | 233.23 | 77.34 | 77.34 | 3 | 0 | 1.28 | 0.000007 | 0.000007 | 0.026981 | 0.026981 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3.5251 | 3.5251 | 103.14 | 103.14 | 52.77 | 52.77 | 3 | 0 | 1.28 | 0.000007 | 0.000007 | 0.016380 | 0.016380 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 2.9492 | 2.9492 | 32.19 | 32.19 | 29.48 | 29.48 | 1 | 0 | 1.28 | 0.000007 | 0.000007 | 0.004607 | 0.004607 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.5700 | 2.5700 | 12.69 | 12.69 | 18.51 | 18.51 | 1 | 0 | 1.28 | 0.000007 | 0.000007 | 0.000293 | 0.000293 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000001** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.5148 | 0.00 | 554.61 | 0.00 | 191.75 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065848 | 0.065848 | 0.000000 | 0.010865 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.5148 | 0.00 | 659.98 | 0.00 | 189.45 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065848 | 0.065848 | 0.000000 | 0.009650 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.4933 | 0.00 | 599.01 | 0.00 | 178.87 | 0 | 3 | 1.28 | 0.000024 | 0.000024 | 0.061753 | 0.061753 | 0.000000 | 0.003647 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 3.4933 | 0.00 | 621.32 | 0.00 | 176.44 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.061753 | 0.061753 | 0.000000 | 0.002164 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 3.4892 | 0.00 | 509.87 | 0.00 | 173.77 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.061766 | 0.061766 | 0.000000 | 0.000491 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.4879 | 0.00 | 562.09 | 0.00 | 171.20 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.060928 | 0.060928 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.4879 | 0.00 | 550.34 | 0.00 | 168.66 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060928 | 0.060928 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.0217 | 0.00 | 680.31 | 0.00 | 188.49 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062435 | 0.062435 | 0.000000 | 0.009133 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 3.9927 | 0.00 | 675.57 | 0.00 | 184.09 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059812 | 0.059812 | 0.000000 | 0.006693 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 3.5981 | 0.00 | 373.08 | 0.00 | 148.38 | 0 | 3 | 10.20 | 0.000013 | 0.000024 | 0.000444 | 0.059645 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 3.9520 | 0.00 | 409.99 | 0.00 | 162.98 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.059101 | 0.059101 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.063449 | 0.063449 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 3.5981 | 0.00 | 453.28 | 0.00 | 145.26 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.000444 | 0.059645 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 3.9520 | 0.00 | 445.41 | 0.00 | 159.55 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.059101 | 0.059101 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064173 | 0.064173 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 3.5747 | 0.00 | 359.93 | 0.00 | 141.14 | 0 | 2 | 10.20 | 0.000013 | 0.000024 | 0.000403 | 0.058743 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 3.9549 | 0.00 | 455.09 | 0.00 | 156.15 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.059164 | 0.059164 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058892 | 0.058892 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.5843 | 0.00 | 356.27 | 0.00 | 138.27 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.000399 | 0.057505 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 3.8925 | 0.00 | 422.39 | 0.00 | 150.16 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057374 | 0.057374 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058846 | 0.058846 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 3.8925 | 0.00 | 345.31 | 0.00 | 146.54 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.053353 | 0.053353 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.061163 | 0.061163 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 3.8715 | 0.00 | 401.46 | 0.00 | 142.06 | 0 | 5 | 1.28 | 0.000024 | 0.000024 | 0.052626 | 0.052626 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.061949 | 0.061949 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 3.8715 | 0.00 | 373.85 | 0.00 | 138.27 | 0 | 4 | 1.28 | 0.000024 | 0.000024 | 0.052626 | 0.052626 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 3.8715 | 0.00 | 301.53 | 0.00 | 134.37 | 0 | 39 | 1.28 | 0.000024 | 0.000024 | 0.047868 | 0.047868 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057474 | 0.057474 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 3.8568 | 0.00 | 271.84 | 0.00 | 129.86 | 0 | 33 | 1.28 | 0.000024 | 0.000024 | 0.047365 | 0.047365 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059149 | 0.059149 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 3.8678 | 0.00 | 310.79 | 0.00 | 126.10 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.000269 | 0.048933 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 3.8568 | 0.00 | 274.73 | 0.00 | 125.74 | 0 | 13 | 1.28 | 0.000024 | 0.000024 | 0.047365 | 0.047365 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057553 | 0.057553 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 3.8678 | 0.00 | 258.16 | 0.00 | 121.83 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000259 | 0.047747 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 3.7453 | 0.00 | 211.58 | 0.00 | 117.97 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045552 | 0.045552 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057567 | 0.057567 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 3.8132 | 0.00 | 241.69 | 0.00 | 115.74 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.000216 | 0.045704 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 3.7502 | 0.00 | 216.85 | 0.00 | 113.82 | 0 | 35 | 1.28 | 0.000024 | 0.000024 | 0.042936 | 0.042936 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055888 | 0.055888 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 3.6988 | 0.00 | 198.10 | 0.00 | 107.86 | 0 | 44 | 1.28 | 0.000024 | 0.000024 | 0.040452 | 0.040452 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043650 | 0.043650 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053096 | 0.053096 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 3.6650 | 0.00 | 221.93 | 0.00 | 102.32 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.000132 | 0.038742 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 3.4169 | 0.00 | 165.62 | 0.00 | 95.40 | 0 | 8 | 1.28 | 0.000024 | 0.000024 | 0.040452 | 0.040452 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 3.7502 | 3.7502 | 290.74 | 290.74 | 104.70 | 104.70 | 3 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042936 | 0.042936 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 3.6591 | 196.08 | 217.35 | 68.41 | 97.41 | 3 | 8 | 1.64 | 0.000013 | 0.000024 | 0.000129 | 0.038441 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 3.4250 | 3.4250 | 350.52 | 176.38 | 91.17 | 91.17 | 2 | 3 | 1.28 | 0.000024 | 0.000024 | 0.040985 | 0.040985 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042222 | 0.042222 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.050259 | 0.050259 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 3.6472 | 187.17 | 230.67 | 64.90 | 92.11 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.000124 | 0.037823 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 3.4087 | 3.4087 | 312.84 | 142.86 | 86.08 | 86.08 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.037904 | 0.037904 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 3.6822 | 3.6822 | 319.22 | 319.22 | 92.99 | 92.99 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.037635 | 0.037635 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 3.6349 | 158.64 | 164.95 | 61.19 | 86.55 | 0 | 4 | 1.64 | 0.000013 | 0.000024 | 0.000106 | 0.034699 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 3.3736 | 3.3736 | 279.62 | 131.69 | 80.32 | 80.32 | 6 | 20 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 3.6411 | 3.6411 | 293.18 | 293.18 | 86.69 | 86.69 | 2 | 7 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 3.5962 | 3.5962 | 287.76 | 144.56 | 80.09 | 80.09 | 1 | 2 | 1.64 | 0.000024 | 0.000024 | 0.032215 | 0.032215 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 3.3736 | 3.3736 | 264.56 | 125.60 | 75.14 | 75.14 | 6 | 12 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.6411 | 3.6411 | 161.83 | 161.83 | 81.09 | 81.09 | 5 | 12 | 1.28 | 0.000024 | 0.000024 | 0.034999 | 0.034999 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 3.7918 | 3.7918 | 304.63 | 304.63 | 84.45 | 84.45 | 6 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043318 | 0.043318 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 3.4931 | 3.4931 | 216.77 | 109.67 | 72.03 | 72.03 | 1 | 7 | 1.64 | 0.000024 | 0.000024 | 0.027260 | 0.027260 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 3.3246 | 3.3246 | 227.39 | 92.09 | 68.55 | 68.55 | 2 | 11 | 1.28 | 0.000024 | 0.000024 | 0.031223 | 0.031223 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 3.5471 | 3.5471 | 235.54 | 235.54 | 73.14 | 73.14 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.029841 | 0.029841 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 3.7961 | 3.7961 | 286.54 | 132.10 | 78.28 | 78.28 | 3 | 4 | 1.28 | 0.000024 | 0.000024 | 0.037981 | 0.037981 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.3771 | 3.3771 | 159.60 | 82.27 | 63.57 | 63.57 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.020767 | 0.020767 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 3.2311 | 3.2311 | 132.69 | 93.34 | 60.82 | 60.82 | 1 | 1 | 1.28 | 0.000024 | 0.000024 | 0.024832 | 0.024832 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.4511 | 3.4511 | 150.31 | 150.31 | 64.96 | 64.96 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.024832 | 0.024832 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.6650 | 3.6650 | 202.46 | 110.86 | 68.99 | 68.99 | 1 | 2 | 1.28 | 0.000024 | 0.000024 | 0.033574 | 0.033574 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.3671 | 3.3671 | 140.27 | 72.86 | 56.69 | 56.69 | 10 | 4 | 1.64 | 0.000024 | 0.000024 | 0.020363 | 0.020363 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.1605 | 3.1605 | 103.72 | 65.29 | 53.21 | 53.21 | 10 | 1 | 1.28 | 0.000024 | 0.000024 | 0.019567 | 0.019567 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.5091 | 3.5091 | 165.76 | 165.76 | 59.08 | 59.08 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.026989 | 0.026989 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.1573 | 3.1573 | 81.11 | 49.82 | 46.03 | 46.03 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.011894 | 0.011894 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.2931 | 3.2931 | 80.81 | 80.81 | 48.01 | 48.01 | 1 | 2 | 1.28 | 0.000024 | 0.000024 | 0.016457 | 0.016457 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.0239 | 3.0239 | 27.89 | 27.89 | 36.00 | 36.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.007843 | 0.007843 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.0076 | 3.0076 | 36.76 | 36.76 | 25.32 | 25.32 | 3 | 0 | 1.28 | 0.000024 | 0.000024 | 0.008244 | 0.008244 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.4607 | 4.4607 | 705.92 | 705.92 | 131.60 | 131.60 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.054402 | 0.054402 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.4082 | 4.4082 | 610.54 | 610.54 | 121.59 | 121.59 | 5 | 0 | 1.28 | 0.000004 | 0.000004 | 0.054213 | 0.054213 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.4208 | 4.4208 | 567.80 | 567.80 | 116.89 | 116.89 | 19 | 0 | 1.28 | 0.000004 | 0.000004 | 0.051002 | 0.051002 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.3964 | 4.3964 | 486.38 | 486.38 | 110.39 | 110.39 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.051022 | 0.051022 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.2436 | 4.2436 | 360.34 | 360.34 | 94.67 | 94.67 | 10 | 0 | 1.28 | 0.000004 | 0.000004 | 0.049171 | 0.049171 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.1541 | 4.1541 | 278.93 | 278.93 | 84.58 | 84.58 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.045734 | 0.045734 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3.9529 | 3.9529 | 129.69 | 129.69 | 59.17 | 59.17 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.034611 | 0.034611 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.5291 | 3.5291 | 46.10 | 46.10 | 35.28 | 35.28 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.016931 | 0.016931 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.7802 | 2.7802 | 14.85 | 14.85 | 20.02 | 20.02 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.003564 | 0.003564 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000001** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] $PA = (BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.6365 | 0.00 | 593.66 | 0.00 | 198.39 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076995 | 0.076995 | 0.000000 | 0.014218 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.6365 | 0.00 | 706.45 | 0.00 | 196.01 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076995 | 0.076995 | 0.000000 | 0.013043 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.6170 | 0.00 | 642.18 | 0.00 | 185.20 | 0 | 3 | 1.28 | 0.000024 | 0.000024 | 0.072779 | 0.072779 | 0.000000 | 0.007322 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 3.6170 | 0.00 | 666.10 | 0.00 | 182.68 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.072779 | 0.072779 | 0.000000 | 0.005890 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 3.6143 | 0.00 | 547.07 | 0.00 | 180.00 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.073140 | 0.073140 | 0.000000 | 0.004318 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.6134 | 0.00 | 603.28 | 0.00 | 177.36 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.072200 | 0.072200 | 0.000000 | 0.002732 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.6134 | 0.00 | 590.67 | 0.00 | 174.73 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072200 | 0.072200 | 0.000000 | 0.001102 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2371 | 0.00 | 755.13 | 0.00 | 198.59 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076095 | 0.076095 | 0.000000 | 0.014317 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.2086 | 0.00 | 750.62 | 0.00 | 194.05 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.073275 | 0.073275 | 0.000000 | 0.012051 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 3.7734 | 0.00 | 410.32 | 0.00 | 155.61 | 0 | 3 | 10.20 | 0.000013 | 0.000024 | 0.009723 | 0.076286 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1818 | 0.00 | 459.04 | 0.00 | 172.45 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.074796 | 0.074796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.071830 | 0.071830 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 3.7734 | 0.00 | 498.53 | 0.00 | 152.34 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.009723 | 0.076286 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1818 | 0.00 | 498.70 | 0.00 | 168.82 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.074796 | 0.074796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074919 | 0.074919 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 3.7580 | 0.00 | 397.78 | 0.00 | 148.38 | 0 | 2 | 10.20 | 0.000013 | 0.000024 | 0.009269 | 0.077133 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 4.1837 | 0.00 | 509.26 | 0.00 | 165.19 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.074701 | 0.074701 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065658 | 0.065658 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.7643 | 0.00 | 392.95 | 0.00 | 145.21 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.009073 | 0.074555 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 4.1424 | 0.00 | 478.36 | 0.00 | 159.80 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076360 | 0.076360 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065539 | 0.065539 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 4.1424 | 0.00 | 391.07 | 0.00 | 155.95 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.070669 | 0.070669 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068095 | 0.068095 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 4.1285 | 0.00 | 456.53 | 0.00 | 151.49 | 0 | 5 | 1.28 | 0.000024 | 0.000024 | 0.071012 | 0.071012 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.070341 | 0.070341 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 4.1285 | 0.00 | 425.13 | 0.00 | 147.45 | 0 | 4 | 1.28 | 0.000024 | 0.000024 | 0.071012 | 0.071012 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 4.1285 | 0.00 | 342.90 | 0.00 | 143.29 | 0 | 39 | 1.28 | 0.000024 | 0.000024 | 0.064146 | 0.064146 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.066612 | 0.066612 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 4.1188 | 0.00 | 310.03 | 0.00 | 138.69 | 0 | 33 | 1.28 | 0.000024 | 0.000024 | 0.064317 | 0.064317 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068689 | 0.068689 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 4.1261 | 0.00 | 353.67 | 0.00 | 134.52 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.006930 | 0.065910 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 4.1188 | 0.00 | 313.32 | 0.00 | 134.28 | 0 | 13 | 1.28 | 0.000024 | 0.000024 | 0.064317 | 0.064317 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.067403 | 0.067403 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 4.1261 | 0.00 | 293.79 | 0.00 | 129.96 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.006697 | 0.064192 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 4.0451 | 0.00 | 246.80 | 0.00 | 127.41 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069100 | 0.069100 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068294 | 0.068294 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 4.0900 | 0.00 | 278.04 | 0.00 | 124.14 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.006126 | 0.064613 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 4.0483 | 0.00 | 252.70 | 0.00 | 122.87 | 0 | 35 | 1.28 | 0.000024 | 0.000024 | 0.064521 | 0.064521 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.066163 | 0.066163 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 4.0143 | 0.00 | 233.34 | 0.00 | 117.06 | 0 | 44 | 1.28 | 0.000024 | 0.000024 | 0.064034 | 0.064034 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065674 | 0.065674 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064635 | 0.064635 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 3.9920 | 0.00 | 263.29 | 0.00 | 111.45 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.004785 | 0.063531 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 3.6536 | 0.00 | 189.36 | 0.00 | 102.01 | 0 | 8 | 1.28 | 0.000024 | 0.000024 | 0.064034 | 0.064034 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.0483 | 4.0483 | 338.81 | 338.81 | 113.02 | 113.02 | 3 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064521 | 0.064521 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 2.5874 | 3.9881 | 198.74 | 258.19 | 68.88 | 106.16 | 3 | 8 | 1.64 | 0.000013 | 0.000024 | 0.004737 | 0.063430 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 3.6590 | 3.6590 | 400.05 | 201.30 | 97.40 | 97.40 | 2 | 3 | 1.28 | 0.000024 | 0.000024 | 0.064165 | 0.064165 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.063369 | 0.063369 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062129 | 0.062129 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5834 | 3.9802 | 189.12 | 274.72 | 65.24 | 100.52 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.004642 | 0.063212 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 3.6482 | 3.6482 | 358.35 | 163.64 | 92.13 | 92.13 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.060458 | 0.060458 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 4.0034 | 4.0034 | 377.33 | 377.33 | 101.10 | 101.10 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060381 | 0.060381 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5793 | 3.9721 | 159.79 | 196.98 | 61.41 | 94.57 | 0 | 4 | 1.64 | 0.000013 | 0.000024 | 0.004117 | 0.058462 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 3.6250 | 3.6250 | 322.84 | 152.05 | 86.31 | 86.31 | 6 | 20 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 3.9762 | 3.9762 | 349.62 | 349.62 | 94.67 | 94.67 | 2 | 7 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 1.000000 | 1.000000 | 0.0400 | 0.000001 | 0.000001 | 0.000001 |
| 56 | Ship | Tanker | 35,000 | 3.9465 | 3.9465 | 346.55 | 174.09 | 87.90 | 87.90 | 1 | 2 | 1.64 | 0.000024 | 0.000024 | 0.056546 | 0.056546 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 3.6250 | 3.6250 | 305.46 | 145.01 | 80.74 | 80.74 | 6 | 12 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.9762 | 3.9762 | 192.98 | 192.98 | 88.56 | 88.56 | 5 | 12 | 1.28 | 0.000024 | 0.000024 | 0.058577 | 0.058577 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000001 | 0.000001 |
| 59 | Ship | Container | 35,000 | 4.0758 | 4.0758 | 351.97 | 351.97 | 90.78 | 90.78 | 6 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062339 | 0.062339 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 3.8783 | 3.8783 | 267.22 | 135.19 | 79.97 | 79.97 | 1 | 7 | 1.64 | 0.000024 | 0.000024 | 0.053837 | 0.053837 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 3.5926 | 3.5926 | 265.53 | 107.54 | 74.08 | 74.08 | 2 | 11 | 1.28 | 0.000024 | 0.000024 | 0.056074 | 0.056074 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 3.9141 | 3.9141 | 286.80 | 286.80 | 80.71 | 80.71 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055356 | 0.055356 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 4.0787 | 4.0787 | 330.78 | 152.49 | 84.10 | 84.10 | 3 | 4 | 1.28 | 0.000024 | 0.000024 | 0.053796 | 0.053796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.8016 | 3.8016 | 202.25 | 104.25 | 71.56 | 71.56 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.047021 | 0.047021 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 3.5308 | 3.5308 | 158.44 | 111.46 | 66.46 | 66.46 | 1 | 1 | 1.28 | 0.000024 | 0.000024 | 0.051487 | 0.051487 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.8506 | 3.8506 | 187.12 | 187.12 | 72.48 | 72.48 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051487 | 0.051487 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.9920 | 3.9920 | 240.20 | 131.52 | 75.14 | 75.14 | 1 | 2 | 1.28 | 0.000024 | 0.000024 | 0.054439 | 0.054439 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.7951 | 3.7951 | 178.19 | 92.55 | 63.89 | 63.89 | 10 | 4 | 1.64 | 0.000024 | 0.000024 | 0.046684 | 0.046684 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.4841 | 3.4841 | 126.04 | 79.34 | 58.66 | 58.66 | 10 | 1 | 1.28 | 0.000024 | 0.000024 | 0.045363 | 0.045363 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.8889 | 3.8889 | 203.59 | 203.59 | 65.47 | 65.47 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.052166 | 0.052166 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.6563 | 3.6563 | 108.77 | 66.82 | 53.31 | 53.31 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.035708 | 0.035708 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.7461 | 3.7461 | 104.57 | 104.57 | 54.62 | 54.62 | 1 | 2 | 1.28 | 0.000024 | 0.000024 | 0.041284 | 0.041284 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5681 | 3.5681 | 38.83 | 38.83 | 42.48 | 42.48 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028207 | 0.028207 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5573 | 3.5573 | 51.42 | 51.42 | 29.95 | 29.95 | 3 | 0 | 1.28 | 0.000024 | 0.000024 | 0.030537 | 0.030537 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6851 | 4.6851 | 778.74 | 778.74 | 138.22 | 138.22 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.061418 | 0.061418 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6577 | 4.6577 | 681.60 | 681.60 | 128.47 | 128.47 | 5 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063565 | 0.063565 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6660 | 4.6660 | 632.53 | 632.53 | 123.37 | 123.37 | 19 | 0 | 1.28 | 0.000004 | 0.000004 | 0.059083 | 0.059083 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6498 | 4.6498 | 544.08 | 544.08 | 116.76 | 116.76 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.059964 | 0.059964 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.5488 | 4.5488 | 414.04 | 414.04 | 101.48 | 101.48 | 10 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063764 | 0.063764 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4897 | 4.4897 | 325.81 | 325.81 | 91.41 | 91.41 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063104 | 0.063104 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.3566 | 4.3566 | 157.54 | 157.54 | 65.21 | 65.21 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.055513 | 0.055513 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 4.0765 | 4.0765 | 61.51 | 61.51 | 40.75 | 40.75 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.039897 | 0.039897 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.5813 | 3.5813 | 24.65 | 24.65 | 25.79 | 25.79 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.019611 | 0.019611 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000004** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 4.4584 | 0.00 | 892.35 | 0.00 | 243.23 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.067016 | 0.067016 | 0.000000 | 0.032081 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 4.4584 | 0.00 | 1061.89 | 0.00 | 240.31 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.067016 | 0.067016 | 0.000000 | 0.031123 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 4.4212 | 0.00 | 959.50 | 0.00 | 226.38 | 0 | 3 | 1.28 | 0.000036 | 0.000036 | 0.062814 | 0.062814 | 0.000000 | 0.026201 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 4.4212 | 0.00 | 995.24 | 0.00 | 223.30 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.062814 | 0.062814 | 0.000000 | 0.025030 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 4.4158 | 0.00 | 816.60 | 0.00 | 219.91 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062984 | 0.062984 | 0.000000 | 0.023702 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 4.4139 | 0.00 | 900.20 | 0.00 | 216.66 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.062090 | 0.062090 | 0.000000 | 0.022389 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 4.4139 | 0.00 | 881.39 | 0.00 | 213.45 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062090 | 0.062090 | 0.000000 | 0.021054 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2057 | 0.00 | 743.98 | 0.00 | 197.12 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064700 | 0.064700 | 0.000000 | 0.013594 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.1757 | 0.00 | 738.92 | 0.00 | 192.53 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061960 | 0.061960 | 0.000000 | 0.011270 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 3.7451 | 0.00 | 404.19 | 0.00 | 154.45 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1451 | 0.00 | 451.03 | 0.00 | 170.94 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063374 | 0.063374 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 3.7451 | 0.00 | 491.08 | 0.00 | 151.19 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1451 | 0.00 | 490.00 | 0.00 | 167.34 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.065140 | 0.065140 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 3.7274 | 0.00 | 391.33 | 0.00 | 147.17 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.001868 | 0.063170 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 4.1473 | 0.00 | 500.45 | 0.00 | 163.75 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062266 | 0.062266 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058063 | 0.058063 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.7347 | 0.00 | 386.79 | 0.00 | 144.07 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.001837 | 0.061299 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 4.1000 | 0.00 | 468.63 | 0.00 | 158.16 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.062070 | 0.062070 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057986 | 0.057986 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 4.1000 | 0.00 | 383.11 | 0.00 | 154.35 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057246 | 0.057246 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.060442 | 0.060442 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 4.0840 | 0.00 | 446.74 | 0.00 | 149.85 | 0 | 2 | 1.28 | 0.000036 | 0.000036 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061855 | 0.061855 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 4.0840 | 0.00 | 416.02 | 0.00 | 145.86 | 0 | 3 | 1.28 | 0.000036 | 0.000036 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 4.0840 | 0.00 | 335.55 | 0.00 | 141.75 | 0 | 16 | 1.28 | 0.000036 | 0.000036 | 0.051251 | 0.051251 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057638 | 0.057638 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 4.0727 | 0.00 | 303.13 | 0.00 | 137.14 | 0 | 12 | 1.28 | 0.000036 | 0.000036 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.059514 | 0.059514 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 4.4586 | 0.00 | 412.97 | 0.00 | 145.36 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001311 | 0.052648 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 4.0727 | 0.00 | 306.36 | 0.00 | 132.78 | 0 | 6 | 1.28 | 0.000036 | 0.000036 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058034 | 0.058034 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 4.4586 | 0.00 | 343.05 | 0.00 | 140.43 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001261 | 0.051208 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 3.9866 | 0.00 | 239.71 | 0.00 | 125.57 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052334 | 0.052334 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058442 | 0.058442 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 4.4062 | 0.00 | 322.70 | 0.00 | 133.73 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001103 | 0.050324 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 3.9904 | 0.00 | 245.52 | 0.00 | 121.11 | 0 | 14 | 1.28 | 0.000036 | 0.000036 | 0.048809 | 0.048809 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056539 | 0.056539 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 3.9502 | 0.00 | 225.94 | 0.00 | 115.19 | 0 | 12 | 1.28 | 0.000036 | 0.000036 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.049727 | 0.049727 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.054292 | 0.054292 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 4.2616 | 0.00 | 300.05 | 0.00 | 118.98 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.000761 | 0.046097 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 4.2949 | 0.00 | 261.67 | 0.00 | 119.91 | 0 | 3 | 1.28 | 0.000036 | 0.000036 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.3451 | 4.3451 | 390.31 | 390.31 | 121.31 | 121.31 | 3 | 0 | 1.28 | 0.000036 | 0.000036 | 0.048809 | 0.048809 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 4.2558 | 196.08 | 294.01 | 68.41 | 113.29 | 8 | 4 | 1.64 | 0.000020 | 0.000036 | 0.000750 | 0.045886 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 4.3054 | 4.3054 | 553.90 | 278.72 | 114.61 | 114.61 | 3 | 1 | 1.28 | 0.000036 | 0.000036 | 0.047599 | 0.047599 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047892 | 0.047892 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051584 | 0.051584 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 4.2440 | 187.17 | 312.34 | 64.90 | 107.18 | 1 | 0 | 1.64 | 0.000020 | 0.000036 | 0.000728 | 0.045451 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 4.2841 | 4.2841 | 494.16 | 225.66 | 108.19 | 108.19 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.044239 | 0.044239 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 4.2786 | 4.2786 | 430.99 | 430.99 | 108.05 | 108.05 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.044059 | 0.044059 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 4.2318 | 158.64 | 223.57 | 61.19 | 100.76 | 4 | 0 | 1.64 | 0.000020 | 0.000036 | 0.000630 | 0.041601 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 4.2379 | 4.2379 | 441.25 | 207.82 | 100.90 | 100.90 | 20 | 6 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 4.2379 | 4.2379 | 397.17 | 397.17 | 100.90 | 100.90 | 6 | 2 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000001 | 0.000002 |
| 56 | Ship | Tanker | 35,000 | 4.1933 | 4.1933 | 391.24 | 196.54 | 93.39 | 93.39 | 2 | 1 | 1.64 | 0.000036 | 0.000036 | 0.039387 | 0.039387 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 4.2379 | 4.2379 | 417.49 | 198.20 | 94.39 | 94.39 | 13 | 6 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 4.2379 | 4.2379 | 219.22 | 219.22 | 94.39 | 94.39 | 12 | 5 | 1.28 | 0.000036 | 0.000036 | 0.041816 | 0.041816 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000001 | 0.000005 |
| 59 | Ship | Container | 35,000 | 4.3855 | 4.3855 | 407.49 | 407.49 | 97.67 | 97.67 | 6 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047991 | 0.047991 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000000 | 0.000002 |
| 60 | Ship | Tanker | 30,000 | 4.0894 | 4.0894 | 297.09 | 150.31 | 84.32 | 84.32 | 7 | 0 | 1.64 | 0.000036 | 0.000036 | 0.035441 | 0.035441 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 4.1728 | 4.1728 | 358.22 | 145.07 | 86.04 | 86.04 | 10 | 3 | 1.28 | 0.000036 | 0.000036 | 0.038633 | 0.038633 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 4.1440 | 4.1440 | 321.49 | 321.49 | 85.45 | 85.45 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.037551 | 0.037551 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 4.3897 | 4.3897 | 383.15 | 176.63 | 90.51 | 90.51 | 4 | 3 | 1.28 | 0.000036 | 0.000036 | 0.041149 | 0.041149 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.9703 | 3.9703 | 220.60 | 113.71 | 74.73 | 74.73 | 1 | 0 | 1.64 | 0.000036 | 0.000036 | 0.028823 | 0.028823 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 4.0466 | 4.0466 | 208.12 | 146.40 | 76.17 | 76.17 | 1 | 1 | 1.28 | 0.000036 | 0.000036 | 0.033052 | 0.033052 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 4.0466 | 4.0466 | 206.65 | 206.65 | 76.17 | 76.17 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033052 | 0.033052 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 4.2616 | 4.2616 | 273.73 | 149.88 | 80.22 | 80.22 | 2 | 1 | 1.28 | 0.000036 | 0.000036 | 0.039156 | 0.039156 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.9600 | 3.9600 | 194.02 | 100.77 | 66.67 | 66.67 | 4 | 9 | 1.64 | 0.000036 | 0.000036 | 0.028446 | 0.028446 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.9496 | 3.9496 | 161.97 | 101.96 | 66.49 | 66.49 | 2 | 10 | 1.28 | 0.000036 | 0.000036 | 0.027436 | 0.027436 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 4.1056 | 4.1056 | 226.91 | 226.91 | 69.12 | 69.12 | 2 | 0 | 1.28 | 0.000036 | 0.000036 | 0.034567 | 0.034567 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.7383 | 3.7383 | 113.70 | 69.85 | 54.51 | 54.51 | 1 | 0 | 1.64 | 0.000036 | 0.000036 | 0.018944 | 0.018944 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.8827 | 3.8827 | 112.33 | 112.33 | 56.61 | 56.61 | 1 | 1 | 1.28 | 0.000036 | 0.000036 | 0.023934 | 0.023934 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5932 | 3.5932 | 39.38 | 39.38 | 42.78 | 42.78 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.013574 | 0.013574 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5752 | 3.5752 | 51.94 | 51.94 | 30.10 | 30.10 | 2 | 0 | 1.28 | 0.000036 | 0.000036 | 0.014640 | 0.014640 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6540 | 4.6540 | 768.44 | 768.44 | 137.30 | 137.30 | 1 | 0 | 1.28 | 0.000006 | 0.000006 | 0.053600 | 0.053600 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6217 | 4.6217 | 671.09 | 671.09 | 127.47 | 127.47 | 5 | 0 | 1.28 | 0.000006 | 0.000006 | 0.054428 | 0.054428 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6310 | 4.6310 | 623.07 | 623.07 | 122.45 | 122.45 | 18 | 0 | 1.28 | 0.000006 | 0.000006 | 0.050608 | 0.050608 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6128 | 4.6128 | 535.46 | 535.46 | 115.83 | 115.83 | 11 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051012 | 0.051012 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.4979 | 4.4979 | 404.83 | 404.83 | 100.35 | 100.35 | 11 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051765 | 0.051765 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4296 | 4.4296 | 317.15 | 317.15 | 90.19 | 90.19 | 2 | 0 | 1.28 | 0.000006 | 0.000006 | 0.049628 | 0.049628 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.2730 | 4.2730 | 151.55 | 151.55 | 63.96 | 63.96 | 3 | 0 | 1.28 | 0.000006 | 0.000006 | 0.040202 | 0.040202 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.9292 | 3.9292 | 57.14 | 57.14 | 39.27 | 39.27 | 1 | 0 | 1.28 | 0.000006 | 0.000006 | 0.023659 | 0.023659 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.2707 | 3.2707 | 20.56 | 20.56 | 23.56 | 23.56 | 1 | 0 | 1.28 | 0.000006 | 0.000006 | 0.007671 | 0.007671 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000014** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 4.4584 | 0.00 | 892.35 | 0.00 | 243.23 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.067016 | 0.067016 | 0.000000 | 0.032081 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 4.4584 | 0.00 | 1061.89 | 0.00 | 240.31 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.067016 | 0.067016 | 0.000000 | 0.031123 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 4.4212 | 0.00 | 959.50 | 0.00 | 226.38 | 0 | 3 | 1.28 | 0.000028 | 0.000028 | 0.062814 | 0.062814 | 0.000000 | 0.026201 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 4.4212 | 0.00 | 995.24 | 0.00 | 223.30 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.062814 | 0.062814 | 0.000000 | 0.025030 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 4.4158 | 0.00 | 816.60 | 0.00 | 219.91 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062984 | 0.062984 | 0.000000 | 0.023702 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 4.4139 | 0.00 | 900.20 | 0.00 | 216.66 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.062090 | 0.062090 | 0.000000 | 0.022389 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 4.4139 | 0.00 | 881.39 | 0.00 | 213.45 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062090 | 0.062090 | 0.000000 | 0.021054 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2057 | 0.00 | 743.98 | 0.00 | 197.12 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064700 | 0.064700 | 0.000000 | 0.013594 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.1757 | 0.00 | 738.92 | 0.00 | 192.53 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061960 | 0.061960 | 0.000000 | 0.011270 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 3.7451 | 0.00 | 404.19 | 0.00 | 154.45 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1451 | 0.00 | 451.03 | 0.00 | 170.94 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063374 | 0.063374 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 3.7451 | 0.00 | 491.08 | 0.00 | 151.19 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1451 | 0.00 | 490.00 | 0.00 | 167.34 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.065140 | 0.065140 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 3.7274 | 0.00 | 391.33 | 0.00 | 147.17 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.001868 | 0.063170 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 4.1473 | 0.00 | 500.45 | 0.00 | 163.75 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062266 | 0.062266 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058063 | 0.058063 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.7347 | 0.00 | 386.79 | 0.00 | 144.07 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.001837 | 0.061299 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 4.1000 | 0.00 | 468.63 | 0.00 | 158.16 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.062070 | 0.062070 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057986 | 0.057986 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 4.1000 | 0.00 | 383.11 | 0.00 | 154.35 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057246 | 0.057246 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.060442 | 0.060442 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 4.0840 | 0.00 | 446.74 | 0.00 | 149.85 | 0 | 2 | 1.28 | 0.000028 | 0.000028 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061855 | 0.061855 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 4.0840 | 0.00 | 416.02 | 0.00 | 145.86 | 0 | 3 | 1.28 | 0.000028 | 0.000028 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 4.0840 | 0.00 | 335.55 | 0.00 | 141.75 | 0 | 16 | 1.28 | 0.000028 | 0.000028 | 0.051251 | 0.051251 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057638 | 0.057638 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 4.0727 | 0.00 | 303.13 | 0.00 | 137.14 | 0 | 12 | 1.28 | 0.000028 | 0.000028 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.059514 | 0.059514 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 4.4586 | 0.00 | 412.97 | 0.00 | 145.36 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001311 | 0.052648 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 4.0727 | 0.00 | 306.36 | 0.00 | 132.78 | 0 | 6 | 1.28 | 0.000028 | 0.000028 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058034 | 0.058034 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 4.4586 | 0.00 | 343.05 | 0.00 | 140.43 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001261 | 0.051208 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 3.9866 | 0.00 | 239.71 | 0.00 | 125.57 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052334 | 0.052334 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058442 | 0.058442 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 4.4062 | 0.00 | 322.70 | 0.00 | 133.73 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001103 | 0.050324 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 3.9904 | 0.00 | 245.52 | 0.00 | 121.11 | 0 | 14 | 1.28 | 0.000028 | 0.000028 | 0.048809 | 0.048809 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056539 | 0.056539 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 3.9502 | 0.00 | 225.94 | 0.00 | 115.19 | 0 | 12 | 1.28 | 0.000028 | 0.000028 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.049727 | 0.049727 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.054292 | 0.054292 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 4.2616 | 0.00 | 300.05 | 0.00 | 118.98 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.000761 | 0.046097 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 4.2949 | 0.00 | 261.67 | 0.00 | 119.91 | 0 | 3 | 1.28 | 0.000028 | 0.000028 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.3451 | 4.3451 | 390.31 | 390.31 | 121.31 | 121.31 | 3 | 0 | 1.28 | 0.000028 | 0.000028 | 0.048809 | 0.048809 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 46 | Ship | Tanker | 50,000 | 2.5700 | 4.2558 | 196.08 | 294.01 | 68.41 | 113.29 | 8 | 4 | 1.64 | 0.000015 | 0.000028 | 0.000750 | 0.045886 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 4.3054 | 4.3054 | 553.90 | 278.72 | 114.61 | 114.61 | 3 | 1 | 1.28 | 0.000028 | 0.000028 | 0.047599 | 0.047599 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047892 | 0.047892 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051584 | 0.051584 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 2.5700 | 4.2440 | 187.17 | 312.34 | 64.90 | 107.18 | 1 | 0 | 1.64 | 0.000015 | 0.000028 | 0.000728 | 0.045451 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 4.2841 | 4.2841 | 494.16 | 225.66 | 108.19 | 108.19 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.044239 | 0.044239 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 4.2786 | 4.2786 | 430.99 | 430.99 | 108.05 | 108.05 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.044059 | 0.044059 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 2.5700 | 4.2318 | 158.64 | 223.57 | 61.19 | 100.76 | 4 | 0 | 1.64 | 0.000015 | 0.000028 | 0.000630 | 0.041601 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 4.2379 | 4.2379 | 441.25 | 207.82 | 100.90 | 100.90 | 20 | 6 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 4.2379 | 4.2379 | 397.17 | 397.17 | 100.90 | 100.90 | 6 | 2 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000002 |
| 56 | Ship | Tanker | 35,000 | 4.1933 | 4.1933 | 391.24 | 196.54 | 93.39 | 93.39 | 2 | 1 | 1.64 | 0.000028 | 0.000028 | 0.039387 | 0.039387 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 4.2379 | 4.2379 | 417.49 | 198.20 | 94.39 | 94.39 | 13 | 6 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 4.2379 | 4.2379 | 219.22 | 219.22 | 94.39 | 94.39 | 12 | 5 | 1.28 | 0.000028 | 0.000028 | 0.041816 | 0.041816 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000001 | 0.000004 |
| 59 | Ship | Container | 35,000 | 4.3855 | 4.3855 | 407.49 | 407.49 | 97.67 | 97.67 | 6 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047991 | 0.047991 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 60 | Ship | Tanker | 30,000 | 4.0894 | 4.0894 | 297.09 | 150.31 | 84.32 | 84.32 | 7 | 0 | 1.64 | 0.000028 | 0.000028 | 0.035441 | 0.035441 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 4.1728 | 4.1728 | 358.22 | 145.07 | 86.04 | 86.04 | 10 | 3 | 1.28 | 0.000028 | 0.000028 | 0.038633 | 0.038633 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 4.1440 | 4.1440 | 321.49 | 321.49 | 85.45 | 85.45 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.037551 | 0.037551 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 4.3897 | 4.3897 | 383.15 | 176.63 | 90.51 | 90.51 | 4 | 3 | 1.28 | 0.000028 | 0.000028 | 0.041149 | 0.041149 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 3.9703 | 3.9703 | 220.60 | 113.71 | 74.73 | 74.73 | 1 | 0 | 1.64 | 0.000028 | 0.000028 | 0.028823 | 0.028823 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 4.0466 | 4.0466 | 208.12 | 146.40 | 76.17 | 76.17 | 1 | 1 | 1.28 | 0.000028 | 0.000028 | 0.033052 | 0.033052 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 4.0466 | 4.0466 | 206.65 | 206.65 | 76.17 | 76.17 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033052 | 0.033052 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 4.2616 | 4.2616 | 273.73 | 149.88 | 80.22 | 80.22 | 2 | 1 | 1.28 | 0.000028 | 0.000028 | 0.039156 | 0.039156 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.9600 | 3.9600 | 194.02 | 100.77 | 66.67 | 66.67 | 4 | 9 | 1.64 | 0.000028 | 0.000028 | 0.028446 | 0.028446 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.9496 | 3.9496 | 161.97 | 101.96 | 66.49 | 66.49 | 2 | 10 | 1.28 | 0.000028 | 0.000028 | 0.027436 | 0.027436 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 4.1056 | 4.1056 | 226.91 | 226.91 | 69.12 | 69.12 | 2 | 0 | 1.28 | 0.000028 | 0.000028 | 0.034567 | 0.034567 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.7383 | 3.7383 | 113.70 | 69.85 | 54.51 | 54.51 | 1 | 0 | 1.64 | 0.000028 | 0.000028 | 0.018944 | 0.018944 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.8827 | 3.8827 | 112.33 | 112.33 | 56.61 | 56.61 | 1 | 1 | 1.28 | 0.000028 | 0.000028 | 0.023934 | 0.023934 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5932 | 3.5932 | 39.38 | 39.38 | 42.78 | 42.78 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.013574 | 0.013574 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5752 | 3.5752 | 51.94 | 51.94 | 30.10 | 30.10 | 2 | 0 | 1.28 | 0.000028 | 0.000028 | 0.014640 | 0.014640 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6540 | 4.6540 | 768.44 | 768.44 | 137.30 | 137.30 | 1 | 0 | 1.28 | 0.000005 | 0.000005 | 0.053600 | 0.053600 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6217 | 4.6217 | 671.09 | 671.09 | 127.47 | 127.47 | 5 | 0 | 1.28 | 0.000005 | 0.000005 | 0.054428 | 0.054428 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6310 | 4.6310 | 623.07 | 623.07 | 122.45 | 122.45 | 18 | 0 | 1.28 | 0.000005 | 0.000005 | 0.050608 | 0.050608 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6128 | 4.6128 | 535.46 | 535.46 | 115.83 | 115.83 | 11 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051012 | 0.051012 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.4979 | 4.4979 | 404.83 | 404.83 | 100.35 | 100.35 | 11 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051765 | 0.051765 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4296 | 4.4296 | 317.15 | 317.15 | 90.19 | 90.19 | 2 | 0 | 1.28 | 0.000005 | 0.000005 | 0.049628 | 0.049628 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.2730 | 4.2730 | 151.55 | 151.55 | 63.96 | 63.96 | 3 | 0 | 1.28 | 0.000005 | 0.000005 | 0.040202 | 0.040202 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.9292 | 3.9292 | 57.14 | 57.14 | 39.27 | 39.27 | 1 | 0 | 1.28 | 0.000005 | 0.000005 | 0.023659 | 0.023659 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.2707 | 3.2707 | 20.56 | 20.56 | 23.56 | 23.56 | 1 | 0 | 1.28 | 0.000005 | 0.000005 | 0.007671 | 0.007671 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000011** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

## ANNUAL FREQUENCY OF COLLAPSE - SUMMARY (WATER ELEVATION -0.1 CD)

| Pier ID | Description | Ultimate Lateral Capacity, H (MN) | | Overall Annual Frequency of Collapse, AF | | | Return Period | % Risk |
|---|---|---|---|---|---|---|---|---|
| | | Foundation | Tower | Inbound | Outbound | Total | | |
| 1 | North Tower | **33** | **0** | 0.00000000 | 0.00000000 | 0.00000000 | - | 0% |
| 2 | South Tower | **173** | **0** | 0.00000355 | 0.00001617 | 0.00001972 | 50,707 | 100% |
| | | | **Total for Bridge:** | 0.00000355 | 0.00001617 | 0.00001972 | **50,707** | **100%** |

**Bridge Type:** **Class I**

**Minimum Return Period:** **10,000**

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# VESSEL FLEET CHARACTERISTICS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Size (m) | | Vessel Drafts (m) | | | | Vessel Displacement (tonnes) | | Channel Width, C (m) | Centerline Vessel Transit Path to Edge of Channel, $x_C$ (m) | | | | Minimum Design Impact Speed, $V_{min}$ (m/sec) | Standard Deviation, σ (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length Overall, LOA | Beam, B | Operational Loaded, $D_O$ | Ballasted | | | Loaded, $W_L$ | Ballasted, $W_E$ | | Inbound | | Outbound | | | Loaded | Ballasted |
| | | | | | | | Stern, $D_{ES}$ | Bow, $D_{EB}$ | Average, $D_{AVG}$ | | | | Pier 1 | Pier 2 | Pier 1 | Pier 2 | | | |
| 1 | Ship | Bulk Carrier | 210,000 | 300 | 50 | 15.0 | 9.2 | 5.0 | 7.1 | 180,650 | 85,510 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 2 | Ship | Bulk Carrier | 205,000 | 300 | 50 | 15.0 | 10.0 | 5.8 | 7.9 | 180,670 | 95,160 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 3 | Ship | Bulk Carrier | 185,000 | 292 | 45 | 15.0 | 10.2 | 6.1 | 8.2 | 158,000 | 85,850 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 292 | 292 |
| 4 | Ship | Bulk Carrier | 180,000 | 292 | 45 | 12.3 | 10.4 | 6.3 | 8.4 | 129,390 | 87,840 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 292 | 292 |
| 5 | Ship | Bulk Carrier | 175,000 | 289 | 45 | 12.6 | 9.5 | 5.4 | 7.5 | 130,940 | 77,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 289 | 289 |
| 6 | Ship | Bulk Carrier | 170,000 | 288 | 44 | 14.5 | 10.1 | 6.0 | 8.1 | 146,610 | 81,390 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 288 | 288 |
| 7 | Ship | Bulk Carrier | 165,000 | 288 | 44 | 15.0 | 10.0 | 5.9 | 8.0 | 151,460 | 80,280 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 288 | 288 |
| 8 | Ship | Bulk Carrier | 155,000 | 273 | 46 | 15.0 | 9.6 | 5.7 | 7.7 | 149,850 | 76,430 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 273 | 273 |
| 9 | Ship | Bulk Carrier | 150,000 | 269 | 43 | 15.0 | 10.0 | 6.2 | 8.1 | 137,740 | 74,380 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 269 | 269 |
| 10 | Ship | Tanker | 120,000 | 250 | 44 | 11.9 | 8.2 | 4.7 | 6.5 | 101,270 | 54,890 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 250 |
| 11 | Ship | Bulk Carrier | 120,000 | 254 | 43 | 14.5 | 7.6 | 4.0 | 5.8 | 124,980 | 50,000 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 254 | 254 |
| 12 | Ship | Container | 120,000 | 324 | 48 | 12.6 | 12.6 | 12.6 | 12.6 | 120,230 | 120,230 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 324 | 324 |
| 13 | Ship | Tanker | 115,000 | 250 | 44 | 11.9 | 9.3 | 5.8 | 7.6 | 101,120 | 64,160 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 250 |
| 14 | Ship | Bulk Carrier | 115,000 | 254 | 43 | 14.7 | 8.1 | 4.5 | 6.3 | 126,740 | 54,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 254 | 254 |
| 15 | Ship | Container | 115,000 | 300 | 48 | 11.9 | 11.9 | 11.9 | 11.9 | 105,070 | 105,070 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 300 | 300 |
| 16 | Ship | Tanker | 110,000 | 240 | 44 | 11.8 | 8.3 | 4.9 | 6.6 | 95,920 | 53,650 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 240 |
| 17 | Ship | Bulk Carrier | 110,000 | 255 | 43 | 12.3 | 8.2 | 4.6 | 6.4 | 106,510 | 55,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 255 | 255 |
| 18 | Ship | Container | 110,000 | 334 | 43 | 12.3 | 12.3 | 12.3 | 12.3 | 108,560 | 108,560 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 334 | 334 |
| 19 | Ship | Tanker | 105,000 | 244 | 42 | 13.0 | 8.4 | 5.0 | 6.7 | 102,480 | 52,820 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 76 | 244 |
| 20 | Ship | Bulk Carrier | 105,000 | 235 | 43 | 14.0 | 8.3 | 5.0 | 6.7 | 111,780 | 53,100 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 235 | 235 |
| 21 | Ship | Container | 105,000 | 335 | 43 | 12.6 | 12.6 | 12.6 | 12.6 | 111,550 | 111,550 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 335 | 335 |
| 22 | Ship | Bulk Carrier | 100,000 | 235 | 38 | 13.5 | 7.8 | 4.5 | 6.2 | 95,280 | 43,410 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 235 | 235 |
| 23 | Ship | Container | 100,000 | 338 | 46 | 12.8 | 12.8 | 12.8 | 12.8 | 122,370 | 122,370 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 338 | 338 |
| 24 | Ship | Bulk Carrier | 95,000 | 229 | 38 | 12.8 | 8.9 | 5.7 | 7.3 | 88,020 | 50,200 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 25 | Ship | Container | 95,000 | 320 | 46 | 13.6 | 13.6 | 13.6 | 13.6 | 122,750 | 122,750 | 177.0 | 111.0 | 66.0 | 74.5 | 102.5 | 2.57 | 320 | 320 |
| 26 | Ship | Bulk Carrier | 90,000 | 229 | 38 | 12.6 | 8.5 | 5.3 | 6.9 | 86,760 | 47,510 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 27 | Ship | Bulk Carrier | 85,000 | 229 | 32 | 12.7 | 8.2 | 5.0 | 6.6 | 73,730 | 38,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 229 | 229 |
| 28 | Ship | Container | 85,000 | 300 | 40 | 12.0 | 12.0 | 12.0 | 12.0 | 88,300 | 88,300 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 300 | 300 |
| 29 | Ship | Bulk Carrier | 80,000 | 225 | 32 | 12.3 | 7.7 | 4.5 | 6.1 | 70,180 | 34,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 225 | 225 |
| 30 | Ship | Container | 80,000 | 300 | 42 | 12.1 | 12.1 | 12.1 | 12.1 | 93,480 | 93,480 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 300 | 300 |
| 31 | Ship | Tanker | 75,000 | 228 | 34 | 11.3 | 8.3 | 5.1 | 6.7 | 66,730 | 39,570 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 228 |
| 32 | Ship | Bulk Carrier | 75,000 | 225 | 32 | 12.1 | 7.8 | 4.6 | 6.2 | 68,640 | 35,180 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 225 | 225 |
| 33 | Ship | Container | 75,000 | 293 | 40 | 12.3 | 12.3 | 12.3 | 12.3 | 88,600 | 88,600 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 293 | 293 |
| 34 | Ship | Tanker | 70,000 | 228 | 32 | 11.0 | 7.4 | 4.2 | 5.8 | 62,330 | 32,870 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 75 | 228 |
| 35 | Ship | Bulk Carrier | 70,000 | 199 | 36 | 12.2 | 6.5 | 3.7 | 5.1 | 68,720 | 28,730 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 199 | 199 |
| 36 | Ship | Container | 70,000 | 285 | 40 | 11.6 | 11.6 | 11.6 | 11.6 | 81,160 | 81,160 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 37 | Ship | Tanker | 65,000 | 214 | 32 | 10.9 | 7.5 | 4.5 | 6.0 | 57,520 | 31,660 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 73 | 214 |
| 38 | Ship | Bulk Carrier | 65,000 | 200 | 32 | 11.8 | 7.3 | 4.5 | 5.9 | 58,740 | 29,370 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 39 | Ship | Container | 65,000 | 285 | 38 | 12.2 | 12.2 | 12.2 | 12.2 | 79,180 | 79,180 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 40 | Ship | Bulk Carrier | 60,000 | 190 | 32 | 11.6 | 7.2 | 4.5 | 5.9 | 54,690 | 27,580 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 190 | 190 |
| 41 | Ship | General Cargo | 60,000 | 200 | 33 | 11.0 | 11.0 | 11.0 | 11.0 | 49,840 | 49,840 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 42 | Ship | Container | 60,000 | 268 | 35 | 12.0 | 12.0 | 12.0 | 12.0 | 75,320 | 75,320 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 268 | 268 |
| 43 | Ship | Tanker | 55,000 | 184 | 32 | 11.4 | 8.3 | 5.7 | 7.0 | 51,250 | 31,470 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 184 |
| 44 | Ship | Bulk Carrier | 55,000 | 190 | 32 | 11.0 | 7.1 | 4.4 | 5.8 | 51,680 | 27,020 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 190 | 190 |
| 45 | Ship | General Cargo | 55,000 | 200 | 32 | 8.2 | 8.2 | 8.2 | 8.2 | 36,030 | 36,030 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 46 | Ship | Tanker | 50,000 | 183 | 32 | 10.6 | 8.2 | 5.6 | 6.9 | 47,500 | 30,920 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 183 |
| 47 | Ship | Bulk Carrier | 50,000 | 192 | 32 | 10.1 | 7.4 | 4.7 | 6.1 | 47,810 | 28,640 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 192 | 192 |
| 48 | Ship | General Cargo | 50,000 | 200 | 31 | 10.9 | 10.9 | 10.9 | 10.9 | 46,390 | 46,390 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 200 | 200 |
| 49 | Ship | Container | 50,000 | 259 | 32 | 11.3 | 11.3 | 11.3 | 11.3 | 59,010 | 59,010 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 259 | 259 |

# VESSEL FLEET CHARACTERISTICS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Size (m) | | Vessel Drafts (m) | | | | Vessel Displacement (tonnes) | | Channel Width, C (m) | Centerline Vessel Transit Path to Edge of Channel, $x_C$ (m) | | | | Minimum Design Impact Speed, $V_{min}$ (m/sec) | Standard Deviation, σ (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length Overall, LOA | Beam, B | Operational Loaded, $D_O$ | Ballasted | | | Loaded, $W_L$ | Ballasted, $W_E$ | | Inbound | | Outbound | | | Loaded | Ballasted |
| | | | | | | | Stern, $D_{ES}$ | Bow, $D_{EB}$ | Average, $D_{AVG}$ | | | | Pier 1 | Pier 2 | Pier 1 | Pier 2 | | | |
| 50 | Ship | Tanker | 45,000 | 181 | 32 | 10.3 | 8.6 | 6.1 | 7.4 | 45,340 | 32,350 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 71 | 181 |
| 51 | Ship | Bulk Carrier | 45,000 | 188 | 29 | 10.3 | 6.9 | 4.3 | 5.6 | 43,080 | 23,420 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 188 | 188 |
| 52 | Ship | General Cargo | 45,000 | 187 | 29 | 10.1 | 10.1 | 10.1 | 10.1 | 37,670 | 37,670 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 187 | 187 |
| 53 | Ship | Tanker | 40,000 | 179 | 28 | 10.1 | 7.5 | 5.0 | 6.3 | 38,430 | 23,780 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 70 | 179 |
| 54 | Ship | Bulk Carrier | 40,000 | 180 | 30 | 9.6 | 6.6 | 4.1 | 5.4 | 39,540 | 22,040 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 55 | Ship | General Cargo | 40,000 | 180 | 30 | 9.6 | 9.6 | 9.6 | 9.6 | 35,590 | 35,590 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 56 | Ship | Tanker | 35,000 | 173 | 27 | 10.2 | 7.3 | 4.9 | 6.1 | 35,600 | 21,290 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 173 | 173 |
| 57 | Ship | Bulk Carrier | 35,000 | 180 | 30 | 9.3 | 6.4 | 3.9 | 5.2 | 37,960 | 21,020 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 58 | Ship | General Cargo | 35,000 | 180 | 28 | 6.7 | 6.7 | 6.7 | 6.7 | 23,250 | 23,250 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 180 | 180 |
| 59 | Ship | Container | 35,000 | 209 | 30 | 9.3 | 9.3 | 9.3 | 9.3 | 34,600 | 34,600 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 209 | 209 |
| 60 | Ship | Tanker | 30,000 | 159 | 27 | 9.2 | 6.5 | 4.3 | 5.4 | 29,160 | 17,120 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 159 | 159 |
| 61 | Ship | Bulk Carrier | 30,000 | 170 | 27 | 9.6 | 5.8 | 3.4 | 4.6 | 33,110 | 15,870 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 170 | 170 |
| 62 | Ship | General Cargo | 30,000 | 166 | 27 | 9.7 | 9.7 | 9.7 | 9.7 | 29,990 | 29,990 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 166 | 166 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 210 | 23 | 9.3 | 5.0 | 5.0 | 5.0 | 32,470 | 17,460 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 210 | 210 |
| 64 | Ship | Tanker | 25,000 | 146 | 24 | 9.2 | 6.5 | 4.5 | 5.5 | 22,970 | 13,740 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 146 | 146 |
| 65 | Ship | Bulk Carrier | 25,000 | 154 | 26 | 7.7 | 6.8 | 4.6 | 5.7 | 23,000 | 17,030 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 154 | 154 |
| 66 | Ship | General Cargo | 25,000 | 154 | 26 | 8.1 | 8.1 | 8.1 | 8.1 | 22,150 | 22,150 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 154 | 154 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 184 | 24 | 8.3 | 5.0 | 5.0 | 5.0 | 26,090 | 15,720 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 184 | 184 |
| 68 | Ship | Tanker | 20,000 | 145 | 24 | 8.7 | 6.1 | 4.1 | 5.1 | 20,880 | 12,240 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 145 | 145 |
| 69 | Ship | Bulk Carrier | 20,000 | 144 | 23 | 7.7 | 6.1 | 4.1 | 5.1 | 18,790 | 12,450 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 144 | 144 |
| 70 | Ship | General Cargo | 20,000 | 161 | 25 | 8.5 | 8.5 | 8.5 | 8.5 | 23,000 | 23,000 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 161 | 161 |
| 71 | Ship | Tanker | 15,000 | 127 | 20 | 8.1 | 6.3 | 4.5 | 5.4 | 14,280 | 9,520 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 127 | 127 |
| 72 | Ship | General Cargo | 15,000 | 138 | 21 | 7.2 | 7.2 | 7.2 | 7.2 | 14,100 | 14,100 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 138 | 138 |
| 73 | Ship | General Cargo | 10,000 | 118 | 16 | 4.5 | 4.5 | 4.5 | 4.5 | 5,810 | 5,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 118 | 118 |
| 74 | Ship | General Cargo | 5,000 | 117 | 20 | 4.7 | 4.7 | 4.7 | 4.7 | 7,740 | 7,740 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 117 | 117 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 317 | 37 | 8.3 | 8.3 | 8.3 | 8.3 | 61,410 | 61,410 | 142.0 | 93.5 | 48.5 | 57.0 | 85.0 | 2.57 | 317 | 317 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 290 | 36 | 8.5 | 8.5 | 8.5 | 8.5 | 53,680 | 53,680 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 290 | 290 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 294 | 32 | 8.6 | 8.6 | 8.6 | 8.6 | 49,330 | 49,330 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 294 | 294 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 285 | 32 | 8.0 | 8.0 | 8.0 | 8.0 | 44,490 | 44,490 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 285 | 285 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 240 | 32 | 8.1 | 8.1 | 8.1 | 8.1 | 35,120 | 35,120 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 240 | 240 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 220 | 31 | 7.7 | 7.7 | 7.7 | 7.7 | 29,250 | 29,250 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 220 | 220 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 186 | 25 | 6.1 | 6.1 | 6.1 | 6.1 | 15,810 | 15,810 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 186 | 186 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 142 | 18 | 4.9 | 4.9 | 4.9 | 4.9 | 7,050 | 7,050 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 142 | 142 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 103 | 15 | 4.1 | 4.1 | 4.1 | 4.1 | 3,660 | 3,660 | 157.0 | 101.0 | 56.0 | 64.5 | 92.5 | 2.57 | 103 | 103 |

**Notes:**

Weight of Water ($W_W$) = **0.9854** $m^3$/tonne (used to determine ship loaded/ballasted displacement tonnage based on approximate salinity of water in Vancouver Harbor)

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# VESSEL FLEET ANNUAL TRIP FREQUENCY

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Annual Number of Trips (N) | | | | | | Existing Total Trips | Growth Factor [1] | Future Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | | Outbound | | | | | |
| | | | | Loaded | Ballasted | Total | Loaded | Ballasted | Total | | | |
| 1 | Ship | Bulk Carrier | 210,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 2 | Ship | Bulk Carrier | 205,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 3 | Ship | Bulk Carrier | 185,000 | 0 | 3 | 3 | 0 | 3 | 3 | 6 | 1.28 | 8 |
| 4 | Ship | Bulk Carrier | 180,000 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 1.28 | 3 |
| 5 | Ship | Bulk Carrier | 175,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 6 | Ship | Bulk Carrier | 170,000 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1.28 | 1 |
| 7 | Ship | Bulk Carrier | 165,000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 8 | Ship | Bulk Carrier | 155,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 9 | Ship | Bulk Carrier | 150,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 10 | Ship | Tanker | 120,000 | 0 | 3 | 3 | 3 | 0 | 3 | 6 | 10.20 | 61 |
| 11 | Ship | Bulk Carrier | 120,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 12 | Ship | Container | 120,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 13 | Ship | Tanker | 115,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 10.20 | 20 |
| 14 | Ship | Bulk Carrier | 115,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 15 | Ship | Container | 115,000 | 2 | 0 | 2 | 2 | 0 | 2 | 4 | 1.28 | 5 |
| 16 | Ship | Tanker | 110,000 | 0 | 3 | 3 | 2 | 0 | 2 | 5 | 10.20 | 51 |
| 17 | Ship | Bulk Carrier | 110,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 18 | Ship | Container | 110,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 19 | Ship | Tanker | 105,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 10.20 | 20 |
| 20 | Ship | Bulk Carrier | 105,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 21 | Ship | Container | 105,000 | 5 | 0 | 5 | 4 | 0 | 4 | 9 | 1.28 | 12 |
| 22 | Ship | Bulk Carrier | 100,000 | 0 | 2 | 2 | 2 | 1 | 3 | 5 | 1.28 | 6 |
| 23 | Ship | Container | 100,000 | 10 | 0 | 10 | 10 | 0 | 10 | 20 | 1.28 | 26 |
| 24 | Ship | Bulk Carrier | 95,000 | 0 | 5 | 5 | 3 | 2 | 5 | 10 | 1.28 | 13 |
| 25 | Ship | Container | 95,000 | 2 | 0 | 2 | 1 | 0 | 1 | 3 | 1.28 | 4 |
| 26 | Ship | Bulk Carrier | 90,000 | 0 | 4 | 4 | 3 | 2 | 5 | 9 | 1.28 | 12 |
| 27 | Ship | Bulk Carrier | 85,000 | 7 | 39 | 46 | 29 | 17 | 46 | 92 | 1.28 | 118 |
| 28 | Ship | Container | 85,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 29 | Ship | Bulk Carrier | 80,000 | 8 | 33 | 41 | 29 | 12 | 41 | 82 | 1.28 | 105 |
| 30 | Ship | Container | 80,000 | 10 | 0 | 10 | 9 | 0 | 9 | 19 | 1.28 | 24 |
| 31 | Ship | Tanker | 75,000 | 0 | 2 | 2 | 2 | 0 | 2 | 4 | 1.64 | 7 |
| 32 | Ship | Bulk Carrier | 75,000 | 1 | 12 | 13 | 8 | 5 | 13 | 26 | 1.28 | 33 |
| 33 | Ship | Container | 75,000 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 1.28 | 28 |
| 34 | Ship | Tanker | 70,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 35 | Ship | Bulk Carrier | 70,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 36 | Ship | Container | 70,000 | 30 | 0 | 30 | 30 | 0 | 30 | 60 | 1.28 | 77 |
| 37 | Ship | Tanker | 65,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 38 | Ship | Bulk Carrier | 65,000 | 14 | 35 | 49 | 34 | 15 | 49 | 98 | 1.28 | 125 |
| 39 | Ship | Container | 65,000 | 8 | 0 | 8 | 8 | 0 | 8 | 16 | 1.28 | 20 |
| 40 | Ship | Bulk Carrier | 60,000 | 13 | 44 | 57 | 45 | 11 | 56 | 113 | 1.28 | 145 |
| 41 | Ship | General Cargo | 60,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 42 | Ship | Container | 60,000 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 43 | Ship | Tanker | 55,000 | 0 | 2 | 2 | 2 | 1 | 3 | 5 | 1.64 | 8 |
| 44 | Ship | Bulk Carrier | 55,000 | 2 | 8 | 10 | 7 | 3 | 10 | 20 | 1.28 | 26 |
| 45 | Ship | General Cargo | 55,000 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| 46 | Ship | Tanker | 50,000 | 3 | 8 | 11 | 7 | 3 | 10 | 21 | 1.64 | 34 |
| 47 | Ship | Bulk Carrier | 50,000 | 2 | 3 | 5 | 4 | 2 | 6 | 11 | 1.28 | 14 |
| 48 | Ship | General Cargo | 50,000 | 6 | 6 | 12 | 6 | 6 | 12 | 24 | 1.28 | 31 |
| 49 | Ship | Container | 50,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)

# VESSEL FLEET ANNUAL TRIP FREQUENCY

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Annual Number of Trips (N) | | | | | | Existing Total Trips | Growth Factor [1] | Future Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | | Outbound | | | | | |
| | | | | Loaded | Ballasted | Total | Loaded | Ballasted | Total | | | |
| 50 | Ship | Tanker | 45,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.64 | 2 |
| 51 | Ship | Bulk Carrier | 45,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 52 | Ship | General Cargo | 45,000 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 53 | Ship | Tanker | 40,000 | 0 | 5 | 5 | 5 | 0 | 5 | 10 | 1.64 | 16 |
| 54 | Ship | Bulk Carrier | 40,000 | 6 | 20 | 26 | 19 | 6 | 25 | 51 | 1.28 | 65 |
| 55 | Ship | General Cargo | 40,000 | 1 | 6 | 7 | 7 | 2 | 9 | 16 | 1.28 | 20 |
| 56 | Ship | Tanker | 35,000 | 1 | 2 | 3 | 2 | 1 | 3 | 6 | 1.64 | 10 |
| 57 | Ship | Bulk Carrier | 35,000 | 7 | 13 | 20 | 13 | 6 | 19 | 39 | 1.28 | 50 |
| 58 | Ship | General Cargo | 35,000 | 4 | 11 | 15 | 11 | 4 | 15 | 30 | 1.28 | 38 |
| 59 | Ship | Container | 35,000 | 7 | 0 | 7 | 7 | 0 | 7 | 14 | 1.28 | 18 |
| 60 | Ship | Tanker | 30,000 | 0 | 7 | 7 | 7 | 1 | 8 | 15 | 1.64 | 25 |
| 61 | Ship | Bulk Carrier | 30,000 | 3 | 12 | 15 | 10 | 3 | 13 | 28 | 1.28 | 36 |
| 62 | Ship | General Cargo | 30,000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 3 | 4 | 7 | 4 | 3 | 7 | 14 | 1.28 | 18 |
| 64 | Ship | Tanker | 25,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 65 | Ship | Bulk Carrier | 25,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 66 | Ship | General Cargo | 25,000 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 1 | 2 | 3 | 2 | 2 | 4 | 7 | 1.28 | 9 |
| 68 | Ship | Tanker | 20,000 | 10 | 5 | 15 | 4 | 9 | 13 | 28 | 1.64 | 46 |
| 69 | Ship | Bulk Carrier | 20,000 | 10 | 1 | 11 | 2 | 10 | 12 | 23 | 1.28 | 29 |
| 70 | Ship | General Cargo | 20,000 | 1 | 0 | 1 | 2 | 0 | 2 | 3 | 1.28 | 4 |
| 71 | Ship | Tanker | 15,000 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1.64 | 3 |
| 72 | Ship | General Cargo | 15,000 | 2 | 2 | 4 | 1 | 1 | 2 | 6 | 1.28 | 8 |
| 73 | Ship | General Cargo | 10,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.28 | 0 |
| 74 | Ship | General Cargo | 5,000 | 2 | 0 | 2 | 3 | 0 | 3 | 5 | 1.28 | 6 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.28 | 1 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 5 | 0 | 5 | 5 | 0 | 5 | 10 | 1.28 | 13 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 19 | 0 | 19 | 19 | 0 | 19 | 38 | 1.28 | 49 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 10 | 0 | 10 | 11 | 0 | 11 | 21 | 1.28 | 27 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 11 | 0 | 11 | 11 | 0 | 11 | 22 | 1.28 | 28 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 3 | 0 | 3 | 2 | 0 | 2 | 5 | 1.28 | 6 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3 | 0 | 3 | 3 | 0 | 3 | 6 | 1.28 | 8 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1.28 | 3 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1.28 | 1 |
| | | **Total Trips:** | | 254 | 312 | 566 | 433 | 133 | 566 | 1132 | | 1618 |

**Notes:**

[1] As part of the risk analysis, vessel trips will include future growth in the waterway that are projected to the mid-point of the remaining design life (assumed 50 years) of the structure. This equates to growth rates per year as follows for a 25-year projection. GF = (1+PERCENT/100)$^{25}$

- Aframax Tankers (DWT greater than 100,000 tonnes) = 9.735%
- All Other Tankers = 2.0%
- All Other Vessels = 1.0%

# VESSEL FLEET TRANSIT SPEEDS IN MAIN CHANNEL

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Transit Speeds (knots) | | | | Vessel Transit Speeds (m/sec) [1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | Outbound | | Inbound | | Outbound | |
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted |
| 1 | Ship | Bulk Carrier | 210,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 2 | Ship | Bulk Carrier | 205,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 3 | Ship | Bulk Carrier | 185,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 4 | Ship | Bulk Carrier | 180,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 5 | Ship | Bulk Carrier | 175,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 6 | Ship | Bulk Carrier | 170,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 7 | Ship | Bulk Carrier | 165,000 | 7.5 | 7.5 | 9.5 | 9.5 | 3.8583 | 3.8583 | 4.8872 | 4.8872 |
| 8 | Ship | Bulk Carrier | 155,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 9 | Ship | Bulk Carrier | 150,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 10 | Ship | Tanker | 120,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 11 | Ship | Bulk Carrier | 120,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 12 | Ship | Container | 120,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 13 | Ship | Tanker | 115,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 14 | Ship | Bulk Carrier | 115,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 15 | Ship | Container | 115,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 16 | Ship | Tanker | 110,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 17 | Ship | Bulk Carrier | 110,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 18 | Ship | Container | 110,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 19 | Ship | Tanker | 105,000 | 7.0 | 8.0 | 7.0 | 8.0 | 3.6011 | 4.1155 | 3.6011 | 4.1155 |
| 20 | Ship | Bulk Carrier | 105,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 21 | Ship | Container | 105,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 22 | Ship | Bulk Carrier | 100,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 23 | Ship | Container | 100,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 24 | Ship | Bulk Carrier | 95,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 25 | Ship | Container | 95,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 26 | Ship | Bulk Carrier | 90,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 27 | Ship | Bulk Carrier | 85,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 28 | Ship | Container | 85,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 29 | Ship | Bulk Carrier | 80,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 30 | Ship | Container | 80,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 31 | Ship | Tanker | 75,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 32 | Ship | Bulk Carrier | 75,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 33 | Ship | Container | 75,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 34 | Ship | Tanker | 70,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 35 | Ship | Bulk Carrier | 70,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 36 | Ship | Container | 70,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 37 | Ship | Tanker | 65,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 38 | Ship | Bulk Carrier | 65,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 39 | Ship | Container | 65,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 40 | Ship | Bulk Carrier | 60,000 | 9.0 | 9.0 | 9.0 | 9.0 | 4.6300 | 4.6300 | 4.6300 | 4.6300 |
| 41 | Ship | General Cargo | 60,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 42 | Ship | Container | 60,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 43 | Ship | Tanker | 55,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 44 | Ship | Bulk Carrier | 55,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 45 | Ship | General Cargo | 55,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 46 | Ship | Tanker | 50,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 47 | Ship | Bulk Carrier | 50,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 48 | Ship | General Cargo | 50,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 49 | Ship | Container | 50,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |

# VESSEL FLEET TRANSIT SPEEDS IN MAIN CHANNEL

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Vessel Transit Speeds (knots) | | | | Vessel Transit Speeds (m/sec) [1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Inbound | | Outbound | | Inbound | | Outbound | |
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted |
| 50 | Ship | Tanker | 45,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 51 | Ship | Bulk Carrier | 45,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 52 | Ship | General Cargo | 45,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 53 | Ship | Tanker | 40,000 | 7.0 | 9.0 | 7.0 | 10.0 | 3.6011 | 4.6300 | 3.6011 | 5.1444 |
| 54 | Ship | Bulk Carrier | 40,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 55 | Ship | General Cargo | 40,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 56 | Ship | Tanker | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 57 | Ship | Bulk Carrier | 35,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 58 | Ship | General Cargo | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 59 | Ship | Container | 35,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 60 | Ship | Tanker | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 61 | Ship | Bulk Carrier | 30,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 62 | Ship | General Cargo | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 64 | Ship | Tanker | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 65 | Ship | Bulk Carrier | 25,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 66 | Ship | General Cargo | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 68 | Ship | Tanker | 20,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 69 | Ship | Bulk Carrier | 20,000 | 8.0 | 8.0 | 10.0 | 10.0 | 4.1155 | 4.1155 | 5.1444 | 5.1444 |
| 70 | Ship | General Cargo | 20,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 71 | Ship | Tanker | 15,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 72 | Ship | General Cargo | 15,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 73 | Ship | General Cargo | 10,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 74 | Ship | General Cargo | 5,000 | 9.0 | 9.0 | 10.0 | 10.0 | 4.6300 | 4.6300 | 5.1444 | 5.1444 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 10.0 | 10.0 | 10.0 | 10.0 | 5.1444 | 5.1444 | 5.1444 | 5.1444 |

**Notes:**

[1] Conversion (knot to m/sec) = 0.51 (convert vessel transit speeds from knots to meters/second for use in risk assessment equations)

# ABERRANCY BASE RATE COMPUTATIONS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Code Recommended Aberrancy Base Rate, BR | Vessel Traffic Service, VTS | Electronic Chart Display & Information System, ECDIS | Other Navigation Aids | Port Control State, PCS | Pilotage 1 Pilot | Pilotage 2 Pilots (MRA-2) | | Daytime Only Transit Restrictions (MRA-2) | Visibility Restrictions (MRA-2) | Cruise Ship Considerations | Adjusted Aberrancy Base Rate, BR [1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Loaded | Ballasted | | | | Loaded | Ballasted |
| 1 | Ship | Bulk Carrier | 210,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 2 | Ship | Bulk Carrier | 205,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 3 | Ship | Bulk Carrier | 185,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 4 | Ship | Bulk Carrier | 180,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 5 | Ship | Bulk Carrier | 175,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 6 | Ship | Bulk Carrier | 170,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 7 | Ship | Bulk Carrier | 165,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 8 | Ship | Bulk Carrier | 155,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 9 | Ship | Bulk Carrier | 150,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 10 | Ship | Tanker | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 11 | Ship | Bulk Carrier | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 12 | Ship | Container | 120,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 13 | Ship | Tanker | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 14 | Ship | Bulk Carrier | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 15 | Ship | Container | 115,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 16 | Ship | Tanker | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 17 | Ship | Bulk Carrier | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 18 | Ship | Container | 110,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 19 | Ship | Tanker | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 20 | Ship | Bulk Carrier | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 21 | Ship | Container | 105,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 22 | Ship | Bulk Carrier | 100,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 23 | Ship | Container | 100,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 24 | Ship | Bulk Carrier | 95,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 25 | Ship | Container | 95,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 26 | Ship | Bulk Carrier | 90,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 27 | Ship | Bulk Carrier | 85,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 28 | Ship | Container | 85,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 29 | Ship | Bulk Carrier | 80,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 30 | Ship | Container | 80,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 31 | Ship | Tanker | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 32 | Ship | Bulk Carrier | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 33 | Ship | Container | 75,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 34 | Ship | Tanker | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 35 | Ship | Bulk Carrier | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 36 | Ship | Container | 70,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 37 | Ship | Tanker | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 38 | Ship | Bulk Carrier | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 39 | Ship | Container | 65,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 40 | Ship | Bulk Carrier | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 41 | Ship | General Cargo | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 42 | Ship | Container | 60,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 43 | Ship | Tanker | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 44 | Ship | Bulk Carrier | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 45 | Ship | General Cargo | 55,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 46 | Ship | Tanker | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 47 | Ship | Bulk Carrier | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 48 | Ship | General Cargo | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 49 | Ship | Container | 50,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |

# ABERRANCY BASE RATE COMPUTATIONS

| Vessel ID | Vessel Type | Description | Vessel Capacity, DWT (tonnes) | Code Recommended Aberrancy Base Rate, BR | Vessel Traffic Service, VTS | Electronic Chart Display & Information System, ECDIS | Other Navigation Aids | Port Control State, PCS | Pilotage 1 Pilot | Pilotage 2 Pilots (MRA-2) | | Daytime Only Transit Restrictions (MRA-2) | Visibility Restrictions (MRA-2) | Cruise Ship Considerations | Adjusted Aberrancy Base Rate, BR [1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Loaded | Ballasted | | | | Loaded | Ballasted |
| 50 | Ship | Tanker | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 51 | Ship | Bulk Carrier | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 52 | Ship | General Cargo | 45,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 53 | Ship | Tanker | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 0.54 | 1.00 | 1.00 | 1.00 | 1.00 | 1.97E-05 | 3.65E-05 |
| 54 | Ship | Bulk Carrier | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 55 | Ship | General Cargo | 40,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 56 | Ship | Tanker | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 57 | Ship | Bulk Carrier | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 58 | Ship | General Cargo | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 59 | Ship | Container | 35,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 60 | Ship | Tanker | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 61 | Ship | Bulk Carrier | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 62 | Ship | General Cargo | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 64 | Ship | Tanker | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 65 | Ship | Bulk Carrier | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 66 | Ship | General Cargo | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 68 | Ship | Tanker | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 69 | Ship | Bulk Carrier | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 70 | Ship | General Cargo | 20,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 71 | Ship | Tanker | 15,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 72 | Ship | General Cargo | 15,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 73 | Ship | General Cargo | 10,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 74 | Ship | General Cargo | 5,000 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 3.65E-05 | 3.65E-05 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 6.00E-05 | 0.80 | 0.81 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.17 | 6.09E-06 | 6.09E-06 |

**Notes:**

[1] Adjustments to the aberrancy Base Rate (BR) due to waterway current restrictions are accounted for elsewhere in the vessel collision risk analysis (refer to correction factors $R_C$ and $R_{XC}$ for the Probability of Aberrancy at each transit leg).

# MISCELLANEOUS INFORMATION

## CHANNEL CHARACTERISTICS

| | | |
|---|---|---|
| Waterway Current Speed ($V_{min}$) = | **2.57** | m/sec |
| Water Elevation = | **-0.10** | m (based on Chart Datum) |
| Sea Level Rise Adjustment = | **0.10** | m |
| Soft Soil Allowance = | **2.00** | m (assumed depth that vessels can "plow" through soft bottom material or "ride up" on underlying rock) |

## AVAILABLE WATER DEPTH AT PIERS

| Pier ID | Description | Mudline Elevation (m) [1] | | Water Elevation (m) | Soft Soil Allowance (m) | Design Water Depth (m) | |
|---|---|---|---|---|---|---|---|
| | | Inbound | Outbound | | | Inbound | Outbound |
| **1** | **North Tower** | **5.00** | **5.00** | 0.00 | 2.00 | -3.00 | -3.00 |
| **2** | **South Tower** | **-7.00** | **-7.00** | 0.00 | 2.00 | 9.00 | 9.00 |

**Notes:**

[1] Mudline elevation is based on Chart Datum (CD) and was obtained from Nautical Chart 3493

## PROBABILITY OF ABERRANCY VARIABLES FOR EACH VESSEL TRANSIT PATH

| Leg ID | Waterway Region for Bridge Location | Angle of Channel Turn, θ (deg) [1] | Correction Factor, $R_B$ | Current Angle to Vessel Path (deg) [2] | Parallel Current, $V_C$ (m/sec) | Perpendicular Current, $V_{XC}$ (m/sec) | Correction Factor, $R_C$ | Correction Factor, $R_{XC}$ | Vessel Traffic Density | Correction Factor, $R_D$ | Summation ($R_B$*$R_C$*$R_{XC}$*$R_D$) | Aberrancy Distribution [3] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Inbound | Outbound |
| **1** | **Transition** | **44.4795** | 1.4942 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 2.2622 | **0.16** | **N/A** |
| **2** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.40** | **N/A** |
| **3** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.22** | **N/A** |
| **4** | **Turn/Bend** | **44.4795** | 1.9884 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 3.0105 | **0.22** | **N/A** |
| **5** | **Transition** | **28.0177** | 1.3113 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 1.9853 | **N/A** | **0.50** |
| **6** | **Straight** | **0.0000** | 1.0000 | **0.0000** | 2.5700 | 0.0000 | 1.5140 | 1.0000 | **Low** | 1.0 | 1.5140 | **N/A** | **0.50** |

**Notes:**

[1] Angle of the turn region in accordance with information shown on Nautical Chart 3493, AIS transit data near the bridge, and CAN/CSA S6-14 Figure A3.3.1

[2] The angle between the water current direction and each channel transition leg

[3] Distribution of the Probability of Aberrancy for each channel transition leg is established as a ratio of the length of each leg to the overall length being considered (approximately 1 nautical mile or 2000m)

## GEOMETRIC PROBABILITY DISTANCES FOR NORMAL DISTRIBUTION

| Pier ID | Description | Leg 1 [1] | | | Leg 2 [1] | | | Leg 3 [1] | | | Leg 4 [1] | | | Leg 5 [1] | | | Leg 6 [1] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) | $x_1$ (m) | x (m) | $x_2$ (m) |
| 1 | North Tower | **328.75** | 342.54 | **356.34** | **32.88** | 44.83 | **56.78** | **138.33** | 149.19 | **160.06** | **245.78** | 254.19 | **262.59** | **212.19** | 219.89 | **227.60** | **212.19** | 219.89 | **227.60** |
| 2 | South Tower | **684.04** | 701.58 | **719.11** | **356.33** | 371.76 | **387.18** | **274.04** | 288.34 | **302.64** | **197.61** | 209.61 | **221.61** | **239.38** | 250.07 | **260.76** | **239.38** | 250.07 | **260.76** |

**Notes:**

[1] Perpendicular distances at each channel transition leg from the centerline of vessel transit path to the bridge element being considered. Distance "x" is from the centerline of vessel transit path to the centerline of bridge element. Distance "$x_1$" (scaled from CADD drawing) is from the centerline of vessel transit path to the closest edge of the bridge element. Distance "$x_2$" (scaled from CADD drawing) is from the centerline of vessel transit path to the farthest edge of the bridge element.

## PROTECTION FACTOR

| Pier ID | Description | Leg 1 | | Leg 2 | | Leg 3 | | Leg 4 | | Leg 5 | | Leg 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound |
| 1 | North Tower | **0.62** | **N/A** | **0.54** | **N/A** | **0.43** | **N/A** | **0.33** | **N/A** | **N/A** | **0.18** | **N/A** | **0.18** |
| 2 | South Tower | **0.003** | **N/A** | **0.01** | **N/A** | **0.02** | **N/A** | **0.04** | **N/A** | **N/A** | **0.14** | **N/A** | **0.14** |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053804 | 0.053804 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053804 | 0.053804 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049883 | 0.049883 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049883 | 0.049883 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049686 | 0.049686 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048933 | 0.048933 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048933 | 0.048933 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049023 | 0.049023 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046613 | 0.046613 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000027 | 0.044813 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044769 | 0.044769 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.053234 | 0.053234 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000027 | 0.044813 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044769 | 0.044769 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.052415 | 0.052415 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000023 | 0.043133 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044909 | 0.044909 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049831 | 0.049831 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000007 | 0.000013 | 0.000023 | 0.042606 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.041590 | 0.041590 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.049838 | 0.049838 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.038622 | 0.038622 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.051971 | 0.051971 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.037482 | 0.037482 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.051743 | 0.051743 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.037482 | 0.037482 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.034028 | 0.034028 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046859 | 0.046859 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.033282 | 0.033282 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.048248 | 0.048248 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000014 | 0.034704 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.033282 | 0.033282 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.046498 | 0.046498 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000013 | 0.033846 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.029214 | 0.029214 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.045990 | 0.045990 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000010 | 0.031005 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027612 | 0.027612 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.044626 | 0.044626 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.024857 | 0.024857 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.028082 | 0.028082 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.041220 | 0.041220 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.023082 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.024857 | 0.024857 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027612 | 0.027612 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.022778 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.025429 | 0.025429 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.027142 | 0.027142 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.038337 | 0.038337 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000005 | 0.022163 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.023031 | 0.023031 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.022751 | 0.022751 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000004 | 0.020063 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.017939 | 0.017939 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.021103 | 0.021103 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.020355 | 0.020355 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.028844 | 0.028844 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.013690 | 0.013690 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.017043 | 0.017043 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.015832 | 0.015832 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.025304 | 0.025304 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.009200 | 0.009200 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011929 | 0.011929 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011929 | 0.011929 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.019930 | 0.019930 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.008924 | 0.008924 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.008474 | 0.008474 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.013763 | 0.013763 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000013 | 0.004079 | 0.004079 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006623 | 0.006623 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002272 | 0.002272 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002350 | 0.002350 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.045210 | 0.045210 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.043545 | 0.043545 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.041184 | 0.041184 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.040685 | 0.040685 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.035982 | 0.035982 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.031633 | 0.031633 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.020774 | 0.020774 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.007148 | 0.007148 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000709 | 0.000709 | 0.000000 | 0.000000 | 0.6200 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] $PA = (BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096934 | 0.096934 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096934 | 0.096934 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092813 | 0.092813 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092813 | 0.092813 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.093749 | 0.093749 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092706 | 0.092706 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.092706 | 0.092706 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100503 | 0.100503 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.097595 | 0.097595 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.293189 | 0.106299 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.103154 | 0.103154 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.087504 | 0.087504 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.293189 | 0.106299 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.103154 | 0.103154 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.094323 | 0.094323 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.294705 | 0.110550 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.102764 | 0.102764 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.079055 | 0.079055 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000024 | 0.000044 | 0.285780 | 0.105624 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.111152 | 0.111152 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.078824 | 0.078824 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.102892 | 0.102892 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.081631 | 0.081631 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.105471 | 0.105471 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086118 | 0.086118 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.105471 | 0.105471 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.095298 | 0.095298 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.083869 | 0.083869 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096918 | 0.096918 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086484 | 0.086484 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.252373 | 0.098253 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.096918 | 0.096918 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.085819 | 0.085819 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.245976 | 0.095698 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.116646 | 0.116646 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.088159 | 0.088159 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.248120 | 0.101661 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108392 | 0.108392 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.085410 | 0.085410 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.113752 | 0.113752 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.110319 | 0.110319 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086283 | 0.086283 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.253671 | 0.117220 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.113752 | 0.113752 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108392 | 0.108392 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.253883 | 0.117818 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.112639 | 0.112639 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.106464 | 0.106464 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.084655 | 0.084655 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.254313 | 0.119031 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.108759 | 0.108759 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.109304 | 0.109304 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.237028 | 0.111720 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.113108 | 0.113108 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.115396 | 0.115396 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.111142 | 0.111142 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100269 | 0.100269 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.122241 | 0.122241 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.114954 | 0.114954 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.117506 | 0.117506 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.086168 | 0.086168 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.124339 | 0.124339 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123397 | 0.123397 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123397 | 0.123397 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.100539 | 0.100539 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.125108 | 0.125108 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.123280 | 0.123280 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.116137 | 0.116137 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000044 | 0.000044 | 0.128994 | 0.128994 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.122630 | 0.122630 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.124977 | 0.124977 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.138383 | 0.138383 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.075464 | 0.075464 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.081411 | 0.081411 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.075076 | 0.075076 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.077380 | 0.077380 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.091430 | 0.091430 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.096904 | 0.096904 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.101180 | 0.101180 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.111543 | 0.111543 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.137764 | 0.137764 | 0.000000 | 0.000000 | 0.5400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084140 | 0.084140 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084140 | 0.084140 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079884 | 0.079884 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079884 | 0.079884 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.080492 | 0.080492 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079490 | 0.079490 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079490 | 0.079490 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085092 | 0.085092 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082175 | 0.082175 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.054561 | 0.087617 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085406 | 0.085406 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077104 | 0.077104 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.054561 | 0.087617 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085406 | 0.085406 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081802 | 0.081802 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.053453 | 0.089890 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.085187 | 0.085187 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069887 | 0.069887 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.052013 | 0.086279 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.089661 | 0.089661 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069720 | 0.069720 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082758 | 0.082758 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072423 | 0.072423 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084021 | 0.084021 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075631 | 0.075631 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.084021 | 0.084021 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075604 | 0.075604 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072444 | 0.072444 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076364 | 0.076364 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074784 | 0.074784 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.042584 | 0.077904 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076364 | 0.076364 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.073729 | 0.073729 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.041288 | 0.075794 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.087244 | 0.087244 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075238 | 0.075238 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.039718 | 0.078448 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081036 | 0.081036 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072807 | 0.072807 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082780 | 0.082780 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082540 | 0.082540 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072232 | 0.072232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035639 | 0.083755 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082780 | 0.082780 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081036 | 0.081036 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035483 | 0.083911 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.082441 | 0.082441 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.079531 | 0.079531 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.070024 | 0.070024 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.035166 | 0.084216 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078482 | 0.078482 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078636 | 0.078636 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.031893 | 0.078233 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.077409 | 0.077409 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.081232 | 0.081232 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078098 | 0.078098 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076437 | 0.076437 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.078688 | 0.078688 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077743 | 0.077743 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.078142 | 0.078142 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065371 | 0.065371 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.074144 | 0.074144 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077314 | 0.077314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.077314 | 0.077314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.071308 | 0.071308 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.074122 | 0.074122 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072472 | 0.072472 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.075334 | 0.075334 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.065858 | 0.065858 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068904 | 0.068904 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057501 | 0.057501 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.063314 | 0.063314 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.065831 | 0.065831 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.069576 | 0.069576 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.064239 | 0.064239 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.065719 | 0.065719 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.073799 | 0.073799 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.075591 | 0.075591 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.072279 | 0.072279 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.064298 | 0.064298 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.050670 | 0.050670 | 0.000000 | 0.000000 | 0.4300 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062009 | 0.062009 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062009 | 0.062009 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057783 | 0.057783 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057783 | 0.057783 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057925 | 0.057925 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057033 | 0.057033 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057033 | 0.057033 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059479 | 0.059479 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056742 | 0.056742 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001520 | 0.057871 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056930 | 0.056930 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058620 | 0.058620 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001520 | 0.057871 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056930 | 0.056930 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060154 | 0.060154 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001408 | 0.057703 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056929 | 0.056929 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053443 | 0.053443 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000013 | 0.000024 | 0.001384 | 0.055894 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.056588 | 0.056588 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053375 | 0.053375 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051853 | 0.051853 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055835 | 0.055835 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051593 | 0.051593 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057080 | 0.057080 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051593 | 0.051593 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045939 | 0.045939 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.052735 | 0.052735 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045739 | 0.045739 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.054590 | 0.054590 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000971 | 0.047305 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045739 | 0.045739 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053068 | 0.053068 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000932 | 0.045893 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.046908 | 0.046908 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053404 | 0.053404 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000810 | 0.044976 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043476 | 0.043476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051525 | 0.051525 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.041967 | 0.041967 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.044369 | 0.044369 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.049174 | 0.049174 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000549 | 0.040860 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.041967 | 0.041967 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043476 | 0.043476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000540 | 0.040660 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042301 | 0.042301 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042582 | 0.042582 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.046440 | 0.046440 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000523 | 0.040245 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.039047 | 0.039047 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038876 | 0.038876 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000449 | 0.036530 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.034430 | 0.034430 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.038380 | 0.038380 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.036732 | 0.036732 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042687 | 0.042687 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.030775 | 0.030775 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.033728 | 0.033728 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.032723 | 0.032723 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.036007 | 0.036007 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.024656 | 0.024656 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028555 | 0.028555 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028555 | 0.028555 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.034135 | 0.034135 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.024316 | 0.024316 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.023377 | 0.023377 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.029913 | 0.029913 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000024 | 0.000024 | 0.015764 | 0.015764 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.020188 | 0.020188 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.011026 | 0.011026 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.012031 | 0.012031 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.048882 | 0.048882 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.049476 | 0.049476 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.045738 | 0.045738 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.046068 | 0.046068 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.046500 | 0.046500 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.044314 | 0.044314 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.035138 | 0.035138 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.019839 | 0.019839 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.006060 | 0.006060 | 0.000000 | 0.000000 | 0.3300 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062377 | 0.062377 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064824 | 0.064824 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061974 | 0.061974 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061956 | 0.061956 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064396 | 0.064396 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005333 | 0.064870 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062964 | 0.062964 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056126 | 0.056126 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.005213 | 0.062504 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063975 | 0.063975 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056031 | 0.056031 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058501 | 0.058501 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058605 | 0.058605 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.060404 | 0.060404 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052072 | 0.052072 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056283 | 0.056283 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058312 | 0.058312 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003846 | 0.053737 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056884 | 0.056884 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003700 | 0.052089 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.055998 | 0.055998 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057551 | 0.057551 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.003341 | 0.052129 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.055476 | 0.055476 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052781 | 0.052781 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.053560 | 0.053560 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002517 | 0.050382 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002488 | 0.050266 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051160 | 0.051160 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050598 | 0.050598 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.050901 | 0.050901 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)



# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002431 | 0.050018 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047584 | 0.047584 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047491 | 0.047491 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.002121 | 0.045543 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.043662 | 0.043662 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.045667 | 0.045667 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.049839 | 0.049839 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.040997 | 0.040997 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.043182 | 0.043182 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.042467 | 0.042467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.041733 | 0.041733 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.034767 | 0.034767 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.041865 | 0.041865 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.034467 | 0.034467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033286 | 0.033286 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.039483 | 0.039483 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.025001 | 0.025001 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.029700 | 0.029700 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.018840 | 0.018840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.020840 | 0.020840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051602 | 0.051602 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.053055 | 0.053055 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.048796 | 0.048796 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.049443 | 0.049443 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051992 | 0.051992 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.050842 | 0.050842 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.042904 | 0.042904 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.028412 | 0.028412 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.012379 | 0.012379 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.066424 | 0.066424 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062102 | 0.062102 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062377 | 0.062377 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061435 | 0.061435 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064824 | 0.064824 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061974 | 0.061974 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061956 | 0.061956 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005635 | 0.064350 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063027 | 0.063027 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064396 | 0.064396 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005333 | 0.064870 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062964 | 0.062964 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056126 | 0.056126 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.005213 | 0.062504 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063975 | 0.063975 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056031 | 0.056031 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058501 | 0.058501 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058605 | 0.058605 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.060404 | 0.060404 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058660 | 0.058660 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052072 | 0.052072 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056283 | 0.056283 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058312 | 0.058312 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003846 | 0.053737 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052131 | 0.052131 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056884 | 0.056884 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003700 | 0.052089 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.055998 | 0.055998 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057551 | 0.057551 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.003341 | 0.052129 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.055476 | 0.055476 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052781 | 0.052781 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.053560 | 0.053560 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002517 | 0.050382 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050991 | 0.050991 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051690 | 0.051690 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002488 | 0.050266 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051160 | 0.051160 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050598 | 0.050598 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.050901 | 0.050901 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |

Lion's Gate Bridge (LGB)
Burrard Inlet Harbor, Vancouver, British Columbia
Vessel Collision Risk Analysis (CAN/CSA-S6-14 Method II)



# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 1
**Description:** North Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002431 | 0.050018 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047584 | 0.047584 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047491 | 0.047491 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.002121 | 0.045543 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.043662 | 0.043662 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047777 | 0.047777 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.045667 | 0.045667 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.049839 | 0.049839 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.040997 | 0.040997 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.043182 | 0.043182 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.042467 | 0.042467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.041733 | 0.041733 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.034767 | 0.034767 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.038819 | 0.038819 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.041865 | 0.041865 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.034467 | 0.034467 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033286 | 0.033286 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.039483 | 0.039483 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.025001 | 0.025001 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.029700 | 0.029700 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.018840 | 0.018840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.020840 | 0.020840 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051602 | 0.051602 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.053055 | 0.053055 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.048796 | 0.048796 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.049443 | 0.049443 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051992 | 0.051992 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.050842 | 0.050842 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.042904 | 0.042904 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.028412 | 0.028412 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.012379 | 0.012379 | 0.000000 | 0.000000 | 0.1800 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 2.8765 | 0.00 | 412.56 | 0.00 | 156.93 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.007454 | 0.007454 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 2.8765 | 0.00 | 484.39 | 0.00 | 155.05 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.007454 | 0.007454 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 2.8440 | 0.00 | 433.26 | 0.00 | 145.63 | 0 | 3 | 1.28 | 0.000013 | 0.000013 | 0.006193 | 0.006193 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 2.8440 | 0.00 | 444.06 | 0.00 | 143.65 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.006193 | 0.006193 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 2.8328 | 0.00 | 371.51 | 0.00 | 141.08 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.005895 | 0.005895 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 2.8290 | 0.00 | 404.17 | 0.00 | 138.86 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005722 | 0.005722 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 2.8290 | 0.00 | 396.40 | 0.00 | 136.80 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.005722 | 0.005722 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 2.8912 | 0.00 | 387.10 | 0.00 | 135.51 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.004450 | 0.004450 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 2.8592 | 0.00 | 378.34 | 0.00 | 131.83 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.003938 | 0.003938 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 2.6778 | 0.00 | 216.94 | 0.00 | 110.43 | 0 | 3 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002530 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 2.7463 | 0.00 | 197.98 | 0.00 | 113.26 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002774 | 0.002774 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.009908 | 0.009908 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 2.6778 | 0.00 | 276.96 | 0.00 | 108.11 | 0 | 1 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002530 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 2.7463 | 0.00 | 222.40 | 0.00 | 110.87 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002774 | 0.002774 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.007274 | 0.007274 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 2.6129 | 0.00 | 204.78 | 0.00 | 103.17 | 0 | 3 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.001896 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 2.7543 | 0.00 | 230.57 | 0.00 | 108.75 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002845 | 0.002845 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.010348 | 0.010348 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 2.6396 | 0.00 | 207.62 | 0.00 | 101.82 | 0 | 1 | 10.20 | 0.000007 | 0.000013 | 0.000000 | 0.002080 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 2.5809 | 0.00 | 198.65 | 0.00 | 99.56 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.001594 | 0.001594 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.010453 | 0.010453 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 2.5809 | 0.00 | 154.45 | 0.00 | 97.16 | 0 | 2 | 1.28 | 0.000013 | 0.000013 | 0.001485 | 0.001485 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.011186 | 0.011186 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 2.5700 | 0.00 | 196.21 | 0.00 | 94.30 | 0 | 5 | 1.28 | 0.000013 | 0.000013 | 0.001208 | 0.001208 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.009230 | 0.009230 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 2.5700 | 0.00 | 180.09 | 0.00 | 91.79 | 0 | 4 | 1.28 | 0.000013 | 0.000013 | 0.001208 | 0.001208 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 2.5700 | 0.00 | 141.51 | 0.00 | 89.20 | 0 | 39 | 1.28 | 0.000013 | 0.000013 | 0.001102 | 0.001102 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006557 | 0.006557 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 2.5700 | 0.00 | 122.12 | 0.00 | 86.54 | 0 | 33 | 1.28 | 0.000013 | 0.000013 | 0.000950 | 0.000950 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.006735 | 0.006735 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 2.5700 | 0.00 | 147.45 | 0.00 | 83.79 | 0 | 2 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.001088 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 2.5700 | 0.00 | 124.80 | 0.00 | 83.79 | 0 | 12 | 1.28 | 0.000013 | 0.000013 | 0.000950 | 0.000950 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005889 | 0.005889 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 2.5700 | 0.00 | 113.98 | 0.00 | 80.95 | 0 | 1 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.001063 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 2.5700 | 0.00 | 99.62 | 0.00 | 80.95 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000302 | 0.000302 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005151 | 0.005151 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 2.5700 | 0.00 | 109.78 | 0.00 | 78.00 | 0 | 1 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000603 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 2.5700 | 0.00 | 101.84 | 0.00 | 78.00 | 0 | 35 | 1.28 | 0.000013 | 0.000013 | 0.000300 | 0.000300 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.005010 | 0.005010 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 2.5700 | 0.00 | 95.64 | 0.00 | 74.94 | 0 | 44 | 1.28 | 0.000013 | 0.000013 | 0.000164 | 0.000164 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000305 | 0.000305 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.003446 | 0.003446 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 2.5700 | 0.00 | 120.26 | 0.00 | 71.75 | 0 | 2 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000109 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 2.5700 | 0.00 | 93.69 | 0.00 | 71.75 | 0 | 8 | 1.28 | 0.000013 | 0.000013 | 0.000164 | 0.000164 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 2.5700 | 2.5700 | 148.73 | 148.73 | 71.75 | 71.75 | 3 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000300 | 0.000300 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 2.5700 | 0.00 | 117.21 | 0.00 | 68.41 | 0 | 8 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000101 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 2.5700 | 0.00 | 99.90 | 0.00 | 68.41 | 0 | 3 | 1.28 | 0.000013 | 0.000013 | 0.000187 | 0.000187 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000295 | 0.000295 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.002682 | 0.002682 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 1

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 2.5700 | 0.00 | 126.89 | 0.00 | 64.90 | 0 | 0 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000087 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 2.5700 | 0.00 | 81.21 | 0.00 | 64.90 | 0 | 1 | 1.28 | 0.000013 | 0.000013 | 0.000137 | 0.000137 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000128 | 0.000128 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 2.5700 | 0.00 | 84.81 | 0.00 | 61.19 | 0 | 5 | 1.64 | 0.000007 | 0.000013 | 0.000000 | 0.000070 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 2.5700 | 0.00 | 76.43 | 0.00 | 61.19 | 0 | 20 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 2.5700 | 0.00 | 74.69 | 0.00 | 57.24 | 0 | 2 | 1.64 | 0.000013 | 0.000013 | 0.000042 | 0.000042 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 2.5700 | 0.00 | 72.89 | 0.00 | 57.24 | 0 | 13 | 1.28 | 0.000013 | 0.000013 | 0.000078 | 0.000078 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 2.5700 | 2.5700 | 86.64 | 86.64 | 57.24 | 57.24 | 4 | 11 | 1.28 | 0.000013 | 0.000013 | 0.000075 | 0.000075 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000462 | 0.000462 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 2.5700 | 0.00 | 59.36 | 0.00 | 52.99 | 0 | 7 | 1.64 | 0.000013 | 0.000013 | 0.000010 | 0.000010 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 2.5700 | 0.00 | 55.03 | 0.00 | 52.99 | 0 | 12 | 1.28 | 0.000013 | 0.000013 | 0.000032 | 0.000032 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000022 | 0.000022 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 2.5700 | 0.00 | 60.54 | 0.00 | 52.99 | 0 | 4 | 1.28 | 0.000013 | 0.000013 | 0.000426 | 0.000426 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 2.5700 | 0.00 | 47.64 | 0.00 | 48.38 | 0 | 1 | 1.64 | 0.000013 | 0.000013 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 2.5700 | 2.5700 | 92.33 | 59.05 | 48.38 | 48.38 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000006 | 0.000006 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 2.5700 | 2.5700 | 91.03 | 91.03 | 48.38 | 48.38 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000006 | 0.000006 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 2.5700 | 2.5700 | 107.70 | 54.51 | 48.38 | 48.38 | 1 | 2 | 1.28 | 0.000013 | 0.000013 | 0.000094 | 0.000094 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 2.5700 | 2.5700 | 86.19 | 42.44 | 43.27 | 43.27 | 10 | 5 | 1.64 | 0.000013 | 0.000013 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 2.5700 | 2.5700 | 75.43 | 43.17 | 43.27 | 43.27 | 10 | 1 | 1.28 | 0.000013 | 0.000013 | 0.000001 | 0.000001 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 2.5700 | 2.5700 | 94.95 | 94.95 | 43.27 | 43.27 | 1 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000012 | 0.000012 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 2.5700 | 2.5700 | 58.69 | 33.01 | 37.47 | 37.47 | 0 | 1 | 1.64 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 2.5700 | 2.5700 | 54.71 | 54.71 | 37.47 | 37.47 | 2 | 2 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 2.5700 | 2.5700 | 20.15 | 20.15 | 30.60 | 30.60 | 0 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 2.5700 | 2.5700 | 26.84 | 26.84 | 21.63 | 21.63 | 2 | 0 | 1.28 | 0.000013 | 0.000013 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 3.2827 | 3.2827 | 413.61 | 413.61 | 96.84 | 96.84 | 1 | 0 | 1.28 | 0.000002 | 0.000002 | 0.007896 | 0.007896 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 3.0989 | 3.0989 | 322.19 | 322.19 | 85.47 | 85.47 | 5 | 0 | 1.28 | 0.000002 | 0.000002 | 0.005259 | 0.005259 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 3.1338 | 3.1338 | 302.78 | 302.78 | 82.86 | 82.86 | 19 | 0 | 1.28 | 0.000002 | 0.000002 | 0.005365 | 0.005365 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 3.0659 | 3.0659 | 258.76 | 258.76 | 76.99 | 76.99 | 10 | 0 | 1.28 | 0.000002 | 0.000002 | 0.004619 | 0.004619 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 2.6414 | 2.6414 | 152.47 | 152.47 | 58.93 | 58.93 | 11 | 0 | 1.28 | 0.000002 | 0.000002 | 0.001598 | 0.001598 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 2.5700 | 2.5700 | 117.42 | 117.42 | 52.33 | 52.33 | 3 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000765 | 0.000765 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 2.5700 | 2.5700 | 55.46 | 55.46 | 38.47 | 38.47 | 3 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000111 | 0.000111 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 2.5700 | 2.5700 | 24.45 | 24.45 | 25.69 | 25.69 | 1 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000001 | 0.000001 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.5700 | 2.5700 | 12.69 | 12.69 | 18.51 | 18.51 | 0 | 0 | 1.28 | 0.000002 | 0.000002 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | 0.0030 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] $PA = (BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.3860 | 0.00 | 571.65 | 0.00 | 184.72 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.049977 | 0.049977 | 0.000000 | 0.007050 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.3860 | 0.00 | 671.17 | 0.00 | 182.51 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.049977 | 0.049977 | 0.000000 | 0.005789 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.3622 | 0.00 | 605.52 | 0.00 | 172.16 | 0 | 3 | 1.28 | 0.000044 | 0.000044 | 0.046166 | 0.046166 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 3.3622 | 0.00 | 620.62 | 0.00 | 169.82 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.046166 | 0.046166 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 3.3567 | 0.00 | 521.64 | 0.00 | 167.17 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.045869 | 0.045869 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.3549 | 0.00 | 568.40 | 0.00 | 164.67 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.045161 | 0.045161 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.3549 | 0.00 | 557.48 | 0.00 | 162.23 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.045161 | 0.045161 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 3.7935 | 0.00 | 666.40 | 0.00 | 177.80 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.044565 | 0.044565 | 0.000000 | 0.002999 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 3.7639 | 0.00 | 655.64 | 0.00 | 173.54 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.042274 | 0.042274 | 0.000000 | 0.000346 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 3.4123 | 0.00 | 352.27 | 0.00 | 140.72 | 0 | 3 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.039720 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 3.7087 | 0.00 | 361.05 | 0.00 | 152.94 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.039908 | 0.039908 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.050313 | 0.050313 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 3.4123 | 0.00 | 449.73 | 0.00 | 137.76 | 0 | 1 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.039720 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 3.7087 | 0.00 | 405.58 | 0.00 | 149.72 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.039908 | 0.039908 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.048737 | 0.048737 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 3.3806 | 0.00 | 342.79 | 0.00 | 133.48 | 0 | 3 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.037704 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 3.7126 | 0.00 | 418.93 | 0.00 | 146.59 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.040083 | 0.040083 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.047508 | 0.047508 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.3936 | 0.00 | 343.20 | 0.00 | 130.91 | 0 | 1 | 10.20 | 0.000024 | 0.000044 | 0.000005 | 0.037502 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 3.6277 | 0.00 | 392.50 | 0.00 | 139.94 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.036099 | 0.036099 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.047541 | 0.047541 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 3.6277 | 0.00 | 305.16 | 0.00 | 136.57 | 0 | 2 | 1.28 | 0.000044 | 0.000044 | 0.033629 | 0.033629 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.049568 | 0.049568 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 3.5991 | 0.00 | 384.83 | 0.00 | 132.06 | 0 | 5 | 1.28 | 0.000044 | 0.000044 | 0.032317 | 0.032317 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.048837 | 0.048837 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 3.5991 | 0.00 | 353.21 | 0.00 | 128.54 | 0 | 4 | 1.28 | 0.000044 | 0.000044 | 0.032317 | 0.032317 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 3.5991 | 0.00 | 277.53 | 0.00 | 124.92 | 0 | 39 | 1.28 | 0.000044 | 0.000044 | 0.029471 | 0.029471 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.043780 | 0.043780 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 3.5792 | 0.00 | 236.85 | 0.00 | 120.52 | 0 | 33 | 1.28 | 0.000044 | 0.000044 | 0.028624 | 0.028624 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.045019 | 0.045019 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 3.5942 | 0.00 | 288.40 | 0.00 | 117.18 | 0 | 2 | 1.64 | 0.000024 | 0.000044 | 0.000003 | 0.029969 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 3.5792 | 0.00 | 242.05 | 0.00 | 116.69 | 0 | 12 | 1.28 | 0.000044 | 0.000044 | 0.028624 | 0.028624 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.043203 | 0.043203 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 3.5942 | 0.00 | 222.93 | 0.00 | 113.21 | 0 | 1 | 1.64 | 0.000024 | 0.000044 | 0.000002 | 0.029263 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 3.4277 | 0.00 | 177.21 | 0.00 | 107.96 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.023684 | 0.023684 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.042440 | 0.042440 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 3.5200 | 0.00 | 205.95 | 0.00 | 106.84 | 0 | 1 | 1.64 | 0.000024 | 0.000044 | 0.000002 | 0.026103 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 3.4343 | 0.00 | 181.86 | 0.00 | 104.24 | 0 | 35 | 1.28 | 0.000044 | 0.000044 | 0.022509 | 0.022509 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.041238 | 0.041238 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 3.3645 | 0.00 | 163.91 | 0.00 | 98.11 | 0 | 44 | 1.28 | 0.000044 | 0.000044 | 0.019714 | 0.019714 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.022874 | 0.022874 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.037547 | 0.037547 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 3.3186 | 0.00 | 200.52 | 0.00 | 92.65 | 0 | 2 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017968 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 3.1661 | 0.00 | 142.20 | 0.00 | 88.39 | 0 | 8 | 1.28 | 0.000044 | 0.000044 | 0.019714 | 0.019714 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 3.4343 | 3.4343 | 265.59 | 265.59 | 95.88 | 95.88 | 3 | 0 | 1.28 | 0.000044 | 0.000044 | 0.022509 | 0.022509 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 3.3106 | 0.00 | 194.49 | 0.00 | 88.13 | 0 | 8 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017673 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 3.1770 | 0.00 | 152.66 | 0.00 | 84.57 | 0 | 3 | 1.28 | 0.000044 | 0.000044 | 0.020286 | 0.020286 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.022144 | 0.022144 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.034653 | 0.034653 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 2

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 3.2943 | 0.00 | 208.50 | 0.00 | 83.19 | 0 | 0 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.017081 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 3.1549 | 0.00 | 122.38 | 0.00 | 79.67 | 0 | 1 | 1.28 | 0.000044 | 0.000044 | 0.018201 | 0.018201 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.017924 | 0.017924 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 3.2777 | 0.00 | 137.96 | 0.00 | 78.04 | 0 | 5 | 1.64 | 0.000024 | 0.000044 | 0.000001 | 0.015406 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 3.1072 | 0.00 | 111.72 | 0.00 | 73.98 | 0 | 20 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 3.2251 | 0.00 | 117.62 | 0.00 | 71.83 | 0 | 2 | 1.64 | 0.000044 | 0.000044 | 0.013483 | 0.013483 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 3.1072 | 0.00 | 106.55 | 0.00 | 69.20 | 0 | 13 | 1.28 | 0.000044 | 0.000044 | 0.016234 | 0.016234 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.2861 | 3.2861 | 141.64 | 141.64 | 73.19 | 73.19 | 4 | 11 | 1.28 | 0.000044 | 0.000044 | 0.015685 | 0.015685 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.024064 | 0.024064 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 3.0850 | 0.00 | 85.54 | 0.00 | 63.61 | 0 | 7 | 1.64 | 0.000044 | 0.000044 | 0.009669 | 0.009669 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 3.0406 | 0.00 | 77.03 | 0.00 | 62.70 | 0 | 12 | 1.28 | 0.000044 | 0.000044 | 0.012655 | 0.012655 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.011557 | 0.011557 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 3.4968 | 0.00 | 112.08 | 0.00 | 72.10 | 0 | 4 | 1.28 | 0.000044 | 0.000044 | 0.021316 | 0.021316 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 2.9272 | 0.00 | 61.81 | 0.00 | 55.10 | 0 | 1 | 1.64 | 0.000044 | 0.000044 | 0.006050 | 0.006050 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 2.9135 | 2.9135 | 118.67 | 75.90 | 54.84 | 54.84 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.008214 | 0.008214 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.0279 | 3.0279 | 126.36 | 126.36 | 56.99 | 56.99 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.008214 | 0.008214 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.3186 | 3.3186 | 179.58 | 90.89 | 62.47 | 62.47 | 1 | 2 | 1.28 | 0.000044 | 0.000044 | 0.015626 | 0.015626 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 2.9138 | 2.9138 | 110.79 | 54.56 | 49.06 | 49.06 | 10 | 5 | 1.64 | 0.000044 | 0.000044 | 0.005830 | 0.005830 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 2.8176 | 2.8176 | 90.67 | 51.89 | 47.44 | 47.44 | 10 | 1 | 1.28 | 0.000044 | 0.000044 | 0.005504 | 0.005504 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.1067 | 3.1067 | 138.74 | 138.74 | 52.30 | 52.30 | 1 | 0 | 1.28 | 0.000044 | 0.000044 | 0.009835 | 0.009835 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 2.6286 | 2.6286 | 61.39 | 34.53 | 38.33 | 38.33 | 0 | 1 | 1.64 | 0.000044 | 0.000044 | 0.002314 | 0.002314 | 0.000000 | 0.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 2.8131 | 2.8131 | 65.55 | 65.55 | 41.02 | 41.02 | 2 | 2 | 1.28 | 0.000044 | 0.000044 | 0.004128 | 0.004128 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 2.5700 | 2.5700 | 20.15 | 20.15 | 30.60 | 30.60 | 0 | 0 | 1.28 | 0.000044 | 0.000044 | 0.001174 | 0.001174 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 2.5700 | 2.5700 | 26.84 | 26.84 | 21.63 | 21.63 | 2 | 0 | 1.28 | 0.000044 | 0.000044 | 0.001195 | 0.001195 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.2229 | 4.2229 | 684.46 | 684.46 | 124.58 | 124.58 | 1 | 0 | 1.28 | 0.000007 | 0.000007 | 0.042850 | 0.042850 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.1439 | 4.1439 | 576.13 | 576.13 | 114.30 | 114.30 | 5 | 0 | 1.28 | 0.000007 | 0.000007 | 0.040455 | 0.040455 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.1610 | 4.1610 | 533.81 | 533.81 | 110.02 | 110.02 | 19 | 0 | 1.28 | 0.000007 | 0.000007 | 0.038529 | 0.038529 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.1278 | 4.1278 | 469.04 | 469.04 | 103.65 | 103.65 | 10 | 0 | 1.28 | 0.000007 | 0.000007 | 0.037773 | 0.037773 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 3.9202 | 3.9202 | 335.82 | 335.82 | 87.46 | 87.46 | 11 | 0 | 1.28 | 0.000007 | 0.000007 | 0.031709 | 0.031709 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 3.7986 | 3.7986 | 256.52 | 256.52 | 77.34 | 77.34 | 3 | 0 | 1.28 | 0.000007 | 0.000007 | 0.026981 | 0.026981 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3.5251 | 3.5251 | 104.35 | 104.35 | 52.77 | 52.77 | 3 | 0 | 1.28 | 0.000007 | 0.000007 | 0.016380 | 0.016380 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 2.9492 | 2.9492 | 32.19 | 32.19 | 29.48 | 29.48 | 1 | 0 | 1.28 | 0.000007 | 0.000007 | 0.004607 | 0.004607 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.5700 | 2.5700 | 12.69 | 12.69 | 18.51 | 18.51 | 0 | 0 | 1.28 | 0.000007 | 0.000007 | 0.000293 | 0.000293 | 1.000000 | 1.000000 | 0.0100 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000000** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.5148 | 0.00 | 615.99 | 0.00 | 191.75 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065848 | 0.065848 | 0.000000 | 0.010865 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.5148 | 0.00 | 723.23 | 0.00 | 189.45 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065848 | 0.065848 | 0.000000 | 0.009650 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.4933 | 0.00 | 653.64 | 0.00 | 178.87 | 0 | 3 | 1.28 | 0.000024 | 0.000024 | 0.061753 | 0.061753 | 0.000000 | 0.003647 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 3.4933 | 0.00 | 669.94 | 0.00 | 176.44 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.061753 | 0.061753 | 0.000000 | 0.002164 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 3.4892 | 0.00 | 563.64 | 0.00 | 173.77 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.061766 | 0.061766 | 0.000000 | 0.000491 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.4879 | 0.00 | 614.37 | 0.00 | 171.20 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060928 | 0.060928 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.4879 | 0.00 | 602.55 | 0.00 | 168.66 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.060928 | 0.060928 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.0217 | 0.00 | 748.99 | 0.00 | 188.49 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062435 | 0.062435 | 0.000000 | 0.009133 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 3.9927 | 0.00 | 737.78 | 0.00 | 184.09 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059812 | 0.059812 | 0.000000 | 0.006693 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 3.5981 | 0.00 | 391.67 | 0.00 | 148.38 | 0 | 3 | 10.20 | 0.000013 | 0.000024 | 0.000444 | 0.059645 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 3.9520 | 0.00 | 409.99 | 0.00 | 162.98 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059101 | 0.059101 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.063449 | 0.063449 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 3.5981 | 0.00 | 500.03 | 0.00 | 145.26 | 0 | 1 | 10.20 | 0.000013 | 0.000024 | 0.000444 | 0.059645 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 3.9520 | 0.00 | 460.56 | 0.00 | 159.55 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059101 | 0.059101 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064173 | 0.064173 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 3.5747 | 0.00 | 383.30 | 0.00 | 141.14 | 0 | 3 | 10.20 | 0.000013 | 0.000024 | 0.000403 | 0.058743 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 3.9549 | 0.00 | 475.41 | 0.00 | 156.15 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059164 | 0.059164 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058892 | 0.058892 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.5843 | 0.00 | 382.85 | 0.00 | 138.27 | 0 | 1 | 10.20 | 0.000013 | 0.000024 | 0.000399 | 0.057505 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 3.8925 | 0.00 | 451.88 | 0.00 | 150.16 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057374 | 0.057374 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.058846 | 0.058846 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 3.8925 | 0.00 | 351.32 | 0.00 | 146.54 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.053353 | 0.053353 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.061163 | 0.061163 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 3.8715 | 0.00 | 445.26 | 0.00 | 142.06 | 0 | 5 | 1.28 | 0.000024 | 0.000024 | 0.052626 | 0.052626 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.061949 | 0.061949 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 3.8715 | 0.00 | 408.68 | 0.00 | 138.27 | 0 | 4 | 1.28 | 0.000024 | 0.000024 | 0.052626 | 0.052626 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 3.8715 | 0.00 | 321.11 | 0.00 | 134.37 | 0 | 39 | 1.28 | 0.000024 | 0.000024 | 0.047868 | 0.047868 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057474 | 0.057474 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 3.8568 | 0.00 | 275.02 | 0.00 | 129.86 | 0 | 33 | 1.28 | 0.000024 | 0.000024 | 0.047365 | 0.047365 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.059149 | 0.059149 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 3.8678 | 0.00 | 333.98 | 0.00 | 126.10 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.000269 | 0.048933 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 3.8568 | 0.00 | 281.06 | 0.00 | 125.74 | 0 | 12 | 1.28 | 0.000024 | 0.000024 | 0.047365 | 0.047365 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057553 | 0.057553 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 3.8678 | 0.00 | 258.16 | 0.00 | 121.83 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.000259 | 0.047747 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 3.7453 | 0.00 | 211.58 | 0.00 | 117.97 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.045552 | 0.045552 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.057567 | 0.057567 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 3.8132 | 0.00 | 241.69 | 0.00 | 115.74 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.000216 | 0.045704 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 3.7502 | 0.00 | 216.85 | 0.00 | 113.82 | 0 | 35 | 1.28 | 0.000024 | 0.000024 | 0.042936 | 0.042936 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055888 | 0.055888 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 3.6988 | 0.00 | 198.10 | 0.00 | 107.86 | 0 | 44 | 1.28 | 0.000024 | 0.000024 | 0.040452 | 0.040452 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043650 | 0.043650 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.053096 | 0.053096 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 3.6650 | 0.00 | 244.57 | 0.00 | 102.32 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.000132 | 0.038742 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 3.4169 | 0.00 | 165.62 | 0.00 | 95.40 | 0 | 8 | 1.28 | 0.000024 | 0.000024 | 0.040452 | 0.040452 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 3.7502 | 3.7502 | 316.70 | 316.70 | 104.70 | 104.70 | 3 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042936 | 0.042936 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 3.6591 | 0.00 | 237.60 | 0.00 | 97.41 | 0 | 8 | 1.64 | 0.000013 | 0.000024 | 0.000129 | 0.038441 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 3.4250 | 0.00 | 177.42 | 0.00 | 91.17 | 0 | 3 | 1.28 | 0.000024 | 0.000024 | 0.040985 | 0.040985 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.042222 | 0.042222 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.050259 | 0.050259 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 3

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 3.6472 | 0.00 | 255.56 | 0.00 | 92.11 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.000124 | 0.037823 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 3.4087 | 0.00 | 142.86 | 0.00 | 86.08 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.037904 | 0.037904 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.037635 | 0.037635 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 3.6349 | 0.00 | 169.67 | 0.00 | 86.55 | 0 | 5 | 1.64 | 0.000013 | 0.000024 | 0.000106 | 0.034699 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 3.3736 | 0.00 | 131.69 | 0.00 | 80.32 | 0 | 20 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 3.5962 | 0.00 | 146.25 | 0.00 | 80.09 | 0 | 2 | 1.64 | 0.000024 | 0.000024 | 0.032215 | 0.032215 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 3.3736 | 0.00 | 125.60 | 0.00 | 75.14 | 0 | 13 | 1.28 | 0.000024 | 0.000024 | 0.036252 | 0.036252 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.6411 | 3.6411 | 173.90 | 173.90 | 81.09 | 81.09 | 4 | 11 | 1.28 | 0.000024 | 0.000024 | 0.034999 | 0.034999 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.043318 | 0.043318 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 3.4931 | 0.00 | 109.67 | 0.00 | 72.03 | 0 | 7 | 1.64 | 0.000024 | 0.000024 | 0.027260 | 0.027260 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 3.3246 | 0.00 | 92.09 | 0.00 | 68.55 | 0 | 12 | 1.28 | 0.000024 | 0.000024 | 0.031223 | 0.031223 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.029841 | 0.029841 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 3.7961 | 0.00 | 132.10 | 0.00 | 78.28 | 0 | 4 | 1.28 | 0.000024 | 0.000024 | 0.037981 | 0.037981 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 3.3771 | 0.00 | 82.27 | 0.00 | 63.57 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.020767 | 0.020767 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 3.2311 | 3.2311 | 145.94 | 93.34 | 60.82 | 60.82 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.024832 | 0.024832 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.4511 | 3.4511 | 164.15 | 164.15 | 64.96 | 64.96 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.024832 | 0.024832 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.6650 | 3.6650 | 219.03 | 110.86 | 68.99 | 68.99 | 1 | 2 | 1.28 | 0.000024 | 0.000024 | 0.033574 | 0.033574 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.3671 | 3.3671 | 147.96 | 72.86 | 56.69 | 56.69 | 10 | 5 | 1.64 | 0.000024 | 0.000024 | 0.020363 | 0.020363 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.1605 | 3.1605 | 114.08 | 65.29 | 53.21 | 53.21 | 10 | 1 | 1.28 | 0.000024 | 0.000024 | 0.019567 | 0.019567 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.5091 | 3.5091 | 177.01 | 177.01 | 59.08 | 59.08 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.026989 | 0.026989 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.1573 | 3.1573 | 88.57 | 49.82 | 46.03 | 46.03 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.011894 | 0.011894 | 0.000000 | 0.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.2931 | 3.2931 | 89.83 | 89.83 | 48.01 | 48.01 | 2 | 2 | 1.28 | 0.000024 | 0.000024 | 0.016457 | 0.016457 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.0239 | 3.0239 | 27.89 | 27.89 | 36.00 | 36.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.007843 | 0.007843 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.0076 | 3.0076 | 36.76 | 36.76 | 25.32 | 25.32 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.008244 | 0.008244 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.4607 | 4.4607 | 763.71 | 763.71 | 131.60 | 131.60 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.054402 | 0.054402 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.4082 | 4.4082 | 651.96 | 651.96 | 121.59 | 121.59 | 5 | 0 | 1.28 | 0.000004 | 0.000004 | 0.054213 | 0.054213 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.4208 | 4.4208 | 602.55 | 602.55 | 116.89 | 116.89 | 19 | 0 | 1.28 | 0.000004 | 0.000004 | 0.051002 | 0.051002 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.3964 | 4.3964 | 532.06 | 532.06 | 110.39 | 110.39 | 10 | 0 | 1.28 | 0.000004 | 0.000004 | 0.051022 | 0.051022 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.2436 | 4.2436 | 393.52 | 393.52 | 94.67 | 94.67 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.049171 | 0.049171 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.1541 | 4.1541 | 306.79 | 306.79 | 84.58 | 84.58 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.045734 | 0.045734 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 3.9529 | 3.9529 | 131.21 | 131.21 | 59.17 | 59.17 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.034611 | 0.034611 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.5291 | 3.5291 | 46.10 | 46.10 | 35.28 | 35.28 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.016931 | 0.016931 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 2.7802 | 2.7802 | 14.85 | 14.85 | 20.02 | 20.02 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.003564 | 0.003564 | 1.000000 | 1.000000 | 0.0200 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000001** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 3.6365 | 0.00 | 659.35 | 0.00 | 198.39 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076995 | 0.076995 | 0.000000 | 0.014218 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 3.6365 | 0.00 | 774.14 | 0.00 | 196.01 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076995 | 0.076995 | 0.000000 | 0.013043 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 3.6170 | 0.00 | 700.75 | 0.00 | 185.20 | 0 | 3 | 1.28 | 0.000024 | 0.000024 | 0.072779 | 0.072779 | 0.000000 | 0.007322 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 3.6170 | 0.00 | 718.23 | 0.00 | 182.68 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.072779 | 0.072779 | 0.000000 | 0.005890 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 3.6143 | 0.00 | 604.77 | 0.00 | 180.00 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.073140 | 0.073140 | 0.000000 | 0.004318 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 3.6134 | 0.00 | 659.38 | 0.00 | 177.36 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.072200 | 0.072200 | 0.000000 | 0.002732 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 3.6134 | 0.00 | 646.71 | 0.00 | 174.73 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.072200 | 0.072200 | 0.000000 | 0.001102 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2371 | 0.00 | 831.36 | 0.00 | 198.59 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076095 | 0.076095 | 0.000000 | 0.014317 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.2086 | 0.00 | 819.75 | 0.00 | 194.05 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.073275 | 0.073275 | 0.000000 | 0.012051 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 3.7734 | 0.00 | 430.77 | 0.00 | 155.61 | 0 | 3 | 10.20 | 0.000013 | 0.000024 | 0.009723 | 0.076286 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1818 | 0.00 | 459.04 | 0.00 | 172.45 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074796 | 0.074796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.071830 | 0.071830 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 3.7734 | 0.00 | 549.95 | 0.00 | 152.34 | 0 | 1 | 10.20 | 0.000013 | 0.000024 | 0.009723 | 0.076286 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1818 | 0.00 | 515.66 | 0.00 | 168.82 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074796 | 0.074796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074919 | 0.074919 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 3.7580 | 0.00 | 423.60 | 0.00 | 148.38 | 0 | 3 | 10.20 | 0.000013 | 0.000024 | 0.009269 | 0.077133 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 4.1837 | 0.00 | 531.99 | 0.00 | 165.19 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.074701 | 0.074701 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065658 | 0.065658 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.7643 | 0.00 | 422.27 | 0.00 | 145.21 | 0 | 1 | 10.20 | 0.000013 | 0.000024 | 0.009073 | 0.074555 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 4.1424 | 0.00 | 511.76 | 0.00 | 159.80 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.076360 | 0.076360 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065539 | 0.065539 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 4.1424 | 0.00 | 397.88 | 0.00 | 155.95 | 0 | 2 | 1.28 | 0.000024 | 0.000024 | 0.070669 | 0.070669 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068095 | 0.068095 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 4.1285 | 0.00 | 506.34 | 0.00 | 151.49 | 0 | 5 | 1.28 | 0.000024 | 0.000024 | 0.071012 | 0.071012 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.070341 | 0.070341 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 4.1285 | 0.00 | 464.74 | 0.00 | 147.45 | 0 | 4 | 1.28 | 0.000024 | 0.000024 | 0.071012 | 0.071012 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 4.1285 | 0.00 | 365.17 | 0.00 | 143.29 | 0 | 39 | 1.28 | 0.000024 | 0.000024 | 0.064146 | 0.064146 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.066612 | 0.066612 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 4.1188 | 0.00 | 313.66 | 0.00 | 138.69 | 0 | 33 | 1.28 | 0.000024 | 0.000024 | 0.064317 | 0.064317 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068689 | 0.068689 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 4.1261 | 0.00 | 380.07 | 0.00 | 134.52 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.006930 | 0.065910 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 4.1188 | 0.00 | 320.54 | 0.00 | 134.28 | 0 | 12 | 1.28 | 0.000024 | 0.000024 | 0.064317 | 0.064317 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.067403 | 0.067403 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 4.1261 | 0.00 | 293.79 | 0.00 | 129.96 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.006697 | 0.064192 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 4.0451 | 0.00 | 246.80 | 0.00 | 127.41 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.069100 | 0.069100 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.068294 | 0.068294 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 4.0900 | 0.00 | 278.04 | 0.00 | 124.14 | 0 | 1 | 1.64 | 0.000013 | 0.000024 | 0.006126 | 0.064613 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 4.0483 | 0.00 | 252.70 | 0.00 | 122.87 | 0 | 35 | 1.28 | 0.000024 | 0.000024 | 0.064521 | 0.064521 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.066163 | 0.066163 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 4.0143 | 0.00 | 233.34 | 0.00 | 117.06 | 0 | 44 | 1.28 | 0.000024 | 0.000024 | 0.064034 | 0.064034 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.065674 | 0.065674 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064635 | 0.064635 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 3.9920 | 0.00 | 290.16 | 0.00 | 111.45 | 0 | 2 | 1.64 | 0.000013 | 0.000024 | 0.004785 | 0.063531 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 3.6536 | 0.00 | 189.36 | 0.00 | 102.01 | 0 | 8 | 1.28 | 0.000024 | 0.000024 | 0.064034 | 0.064034 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.0483 | 4.0483 | 369.05 | 369.05 | 113.02 | 113.02 | 3 | 0 | 1.28 | 0.000024 | 0.000024 | 0.064521 | 0.064521 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 3.9881 | 0.00 | 282.24 | 0.00 | 106.16 | 0 | 8 | 1.64 | 0.000013 | 0.000024 | 0.004737 | 0.063430 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 3.6590 | 0.00 | 202.49 | 0.00 | 97.40 | 0 | 3 | 1.28 | 0.000024 | 0.000024 | 0.064165 | 0.064165 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.063369 | 0.063369 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062129 | 0.062129 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Inbound
**Channel Leg:** 4

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 3.9802 | 0.00 | 304.36 | 0.00 | 100.52 | 0 | 0 | 1.64 | 0.000013 | 0.000024 | 0.004642 | 0.063212 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 3.6482 | 0.00 | 163.64 | 0.00 | 92.13 | 0 | 1 | 1.28 | 0.000024 | 0.000024 | 0.060458 | 0.060458 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060381 | 0.060381 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 3.9721 | 0.00 | 202.60 | 0.00 | 94.57 | 0 | 5 | 1.64 | 0.000013 | 0.000024 | 0.004117 | 0.058462 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 3.6250 | 0.00 | 152.05 | 0.00 | 86.31 | 0 | 20 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 3.9465 | 0.00 | 176.12 | 0.00 | 87.90 | 0 | 2 | 1.64 | 0.000024 | 0.000024 | 0.056546 | 0.056546 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 3.6250 | 0.00 | 145.01 | 0.00 | 80.74 | 0 | 13 | 1.28 | 0.000024 | 0.000024 | 0.060835 | 0.060835 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 3.9762 | 3.9762 | 207.38 | 207.38 | 88.56 | 88.56 | 4 | 11 | 1.28 | 0.000024 | 0.000024 | 0.058577 | 0.058577 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000001 | 0.000001 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.062339 | 0.062339 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 3.8783 | 0.00 | 135.19 | 0.00 | 79.97 | 0 | 7 | 1.64 | 0.000024 | 0.000024 | 0.053837 | 0.053837 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 3.5926 | 0.00 | 107.54 | 0.00 | 74.08 | 0 | 12 | 1.28 | 0.000024 | 0.000024 | 0.056074 | 0.056074 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.055356 | 0.055356 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 4.0787 | 0.00 | 152.49 | 0.00 | 84.10 | 0 | 4 | 1.28 | 0.000024 | 0.000024 | 0.053796 | 0.053796 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 3.8016 | 0.00 | 104.25 | 0.00 | 71.56 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.047021 | 0.047021 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 3.5308 | 3.5308 | 174.27 | 111.46 | 66.46 | 66.46 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051487 | 0.051487 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 3.8506 | 3.8506 | 204.35 | 204.35 | 72.48 | 72.48 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.051487 | 0.051487 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 3.9920 | 3.9920 | 259.86 | 131.52 | 75.14 | 75.14 | 1 | 2 | 1.28 | 0.000024 | 0.000024 | 0.054439 | 0.054439 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.7951 | 3.7951 | 187.95 | 92.55 | 63.89 | 63.89 | 10 | 5 | 1.64 | 0.000024 | 0.000024 | 0.046684 | 0.046684 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.4841 | 3.4841 | 138.63 | 79.34 | 58.66 | 58.66 | 10 | 1 | 1.28 | 0.000024 | 0.000024 | 0.045363 | 0.045363 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 3.8889 | 3.8889 | 217.40 | 217.40 | 65.47 | 65.47 | 1 | 0 | 1.28 | 0.000024 | 0.000024 | 0.052166 | 0.052166 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.6563 | 3.6563 | 118.79 | 66.82 | 53.31 | 53.31 | 0 | 1 | 1.64 | 0.000024 | 0.000024 | 0.035708 | 0.035708 | 0.000000 | 0.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.7461 | 3.7461 | 116.25 | 116.25 | 54.62 | 54.62 | 2 | 2 | 1.28 | 0.000024 | 0.000024 | 0.041284 | 0.041284 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5681 | 3.5681 | 38.83 | 38.83 | 42.48 | 42.48 | 0 | 0 | 1.28 | 0.000024 | 0.000024 | 0.028207 | 0.028207 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5573 | 3.5573 | 51.42 | 51.42 | 29.95 | 29.95 | 2 | 0 | 1.28 | 0.000024 | 0.000024 | 0.030537 | 0.030537 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6851 | 4.6851 | 842.49 | 842.49 | 138.22 | 138.22 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.061418 | 0.061418 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6577 | 4.6577 | 727.84 | 727.84 | 128.47 | 128.47 | 5 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063565 | 0.063565 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6660 | 4.6660 | 671.24 | 671.24 | 123.37 | 123.37 | 19 | 0 | 1.28 | 0.000004 | 0.000004 | 0.059083 | 0.059083 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6498 | 4.6498 | 595.19 | 595.19 | 116.76 | 116.76 | 10 | 0 | 1.28 | 0.000004 | 0.000004 | 0.059964 | 0.059964 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.5488 | 4.5488 | 452.17 | 452.17 | 101.48 | 101.48 | 11 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063764 | 0.063764 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4897 | 4.4897 | 358.35 | 358.35 | 91.41 | 91.41 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.063104 | 0.063104 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.3566 | 4.3566 | 159.39 | 159.39 | 65.21 | 65.21 | 3 | 0 | 1.28 | 0.000004 | 0.000004 | 0.055513 | 0.055513 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 4.0765 | 4.0765 | 61.51 | 61.51 | 40.75 | 40.75 | 1 | 0 | 1.28 | 0.000004 | 0.000004 | 0.039897 | 0.039897 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.5813 | 3.5813 | 24.65 | 24.65 | 25.79 | 25.79 | 0 | 0 | 1.28 | 0.000004 | 0.000004 | 0.019611 | 0.019611 | 1.000000 | 1.000000 | 0.0400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000002** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 4.4584 | 0.00 | 991.10 | 0.00 | 243.23 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.067016 | 0.067016 | 0.000000 | 0.032081 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 4.4584 | 0.00 | 1163.65 | 0.00 | 240.31 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.067016 | 0.067016 | 0.000000 | 0.031123 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 4.4212 | 0.00 | 1047.00 | 0.00 | 226.38 | 0 | 3 | 1.28 | 0.000036 | 0.000036 | 0.062814 | 0.062814 | 0.000000 | 0.026201 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 4.4212 | 0.00 | 1073.12 | 0.00 | 223.30 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.062814 | 0.062814 | 0.000000 | 0.025030 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 4.4158 | 0.00 | 902.72 | 0.00 | 219.91 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062984 | 0.062984 | 0.000000 | 0.023702 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 4.4139 | 0.00 | 983.92 | 0.00 | 216.66 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.062090 | 0.062090 | 0.000000 | 0.022389 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 4.4139 | 0.00 | 965.00 | 0.00 | 213.45 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062090 | 0.062090 | 0.000000 | 0.021054 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2057 | 0.00 | 819.08 | 0.00 | 197.12 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.064700 | 0.064700 | 0.000000 | 0.013594 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.1757 | 0.00 | 806.97 | 0.00 | 192.53 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061960 | 0.061960 | 0.000000 | 0.011270 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 3.7451 | 0.00 | 424.33 | 0.00 | 154.45 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1451 | 0.00 | 451.03 | 0.00 | 170.94 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.063374 | 0.063374 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 3.7451 | 0.00 | 541.73 | 0.00 | 151.19 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1451 | 0.00 | 506.67 | 0.00 | 167.34 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.065140 | 0.065140 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 3.7274 | 0.00 | 416.75 | 0.00 | 147.17 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.001868 | 0.063170 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 4.1473 | 0.00 | 522.79 | 0.00 | 163.75 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062266 | 0.062266 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058063 | 0.058063 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.7347 | 0.00 | 415.65 | 0.00 | 144.07 | 0 | 0 | 10.20 | 0.000020 | 0.000036 | 0.001837 | 0.061299 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 4.1000 | 0.00 | 501.34 | 0.00 | 158.16 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.062070 | 0.062070 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057986 | 0.057986 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 4.1000 | 0.00 | 389.78 | 0.00 | 154.35 | 0 | 1 | 1.28 | 0.000036 | 0.000036 | 0.057246 | 0.057246 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.060442 | 0.060442 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 4.0840 | 0.00 | 495.49 | 0.00 | 149.85 | 0 | 2 | 1.28 | 0.000036 | 0.000036 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.061855 | 0.061855 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 4.0840 | 0.00 | 454.78 | 0.00 | 145.86 | 0 | 2 | 1.28 | 0.000036 | 0.000036 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 4.0840 | 0.00 | 357.33 | 0.00 | 141.75 | 0 | 17 | 1.28 | 0.000036 | 0.000036 | 0.051251 | 0.051251 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.057638 | 0.057638 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 4.0727 | 0.00 | 306.68 | 0.00 | 137.14 | 0 | 12 | 1.28 | 0.000036 | 0.000036 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.059514 | 0.059514 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 4.4586 | 0.00 | 443.79 | 0.00 | 145.36 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001311 | 0.052648 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 4.0727 | 0.00 | 313.41 | 0.00 | 132.78 | 0 | 5 | 1.28 | 0.000036 | 0.000036 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058034 | 0.058034 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 4.4586 | 0.00 | 343.05 | 0.00 | 140.43 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001261 | 0.051208 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 3.9866 | 0.00 | 239.71 | 0.00 | 125.57 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.052334 | 0.052334 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.058442 | 0.058442 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 4.4062 | 0.00 | 322.70 | 0.00 | 133.73 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.001103 | 0.050324 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 3.9904 | 0.00 | 245.52 | 0.00 | 121.11 | 0 | 15 | 1.28 | 0.000036 | 0.000036 | 0.048809 | 0.048809 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.056539 | 0.056539 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 3.9502 | 0.00 | 225.94 | 0.00 | 115.19 | 0 | 11 | 1.28 | 0.000036 | 0.000036 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.049727 | 0.049727 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.054292 | 0.054292 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 4.2616 | 0.00 | 330.67 | 0.00 | 118.98 | 0 | 1 | 1.64 | 0.000020 | 0.000036 | 0.000761 | 0.046097 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 4.2949 | 0.00 | 261.67 | 0.00 | 119.91 | 0 | 3 | 1.28 | 0.000036 | 0.000036 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.3451 | 4.3451 | 425.15 | 425.15 | 121.31 | 121.31 | 3 | 0 | 1.28 | 0.000036 | 0.000036 | 0.048809 | 0.048809 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 4.2558 | 0.00 | 321.40 | 0.00 | 113.29 | 0 | 3 | 1.64 | 0.000020 | 0.000036 | 0.000750 | 0.045886 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 4.3054 | 0.00 | 280.36 | 0.00 | 114.61 | 0 | 2 | 1.28 | 0.000036 | 0.000036 | 0.047599 | 0.047599 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047892 | 0.047892 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.051584 | 0.051584 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 5

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 4.2440 | 0.00 | 346.03 | 0.00 | 107.18 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.000728 | 0.045451 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 4.2841 | 0.00 | 225.66 | 0.00 | 108.19 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.044239 | 0.044239 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.044059 | 0.044059 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 4.2318 | 0.00 | 229.96 | 0.00 | 100.76 | 0 | 0 | 1.64 | 0.000020 | 0.000036 | 0.000630 | 0.041601 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 4.2379 | 0.00 | 207.82 | 0.00 | 100.90 | 0 | 6 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 4.1933 | 0.00 | 198.84 | 0.00 | 93.39 | 0 | 1 | 1.64 | 0.000036 | 0.000036 | 0.039387 | 0.039387 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 4.2379 | 0.00 | 198.20 | 0.00 | 94.39 | 0 | 6 | 1.28 | 0.000036 | 0.000036 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 4.2379 | 4.2379 | 235.58 | 235.58 | 94.39 | 94.39 | 11 | 4 | 1.28 | 0.000036 | 0.000036 | 0.041816 | 0.041816 | 1.000000 | 1.000000 | 0.1400 | 0.000003 | 0.000001 | 0.000004 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.047991 | 0.047991 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 4.0894 | 0.00 | 150.31 | 0.00 | 84.32 | 0 | 1 | 1.64 | 0.000036 | 0.000036 | 0.035441 | 0.035441 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 4.1728 | 0.00 | 145.07 | 0.00 | 86.04 | 0 | 3 | 1.28 | 0.000036 | 0.000036 | 0.038633 | 0.038633 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.037551 | 0.037551 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 4.3897 | 0.00 | 176.63 | 0.00 | 90.51 | 0 | 3 | 1.28 | 0.000036 | 0.000036 | 0.041149 | 0.041149 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 3.9703 | 0.00 | 113.71 | 0.00 | 74.73 | 0 | 0 | 1.64 | 0.000036 | 0.000036 | 0.028823 | 0.028823 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 4.0466 | 4.0466 | 228.91 | 146.40 | 76.17 | 76.17 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033052 | 0.033052 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 4.0466 | 4.0466 | 225.68 | 225.68 | 76.17 | 76.17 | 1 | 0 | 1.28 | 0.000036 | 0.000036 | 0.033052 | 0.033052 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 4.2616 | 4.2616 | 296.14 | 149.88 | 80.22 | 80.22 | 2 | 2 | 1.28 | 0.000036 | 0.000036 | 0.039156 | 0.039156 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.9600 | 3.9600 | 204.65 | 100.77 | 66.67 | 66.67 | 4 | 9 | 1.64 | 0.000036 | 0.000036 | 0.028446 | 0.028446 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.9496 | 3.9496 | 178.15 | 101.96 | 66.49 | 66.49 | 2 | 10 | 1.28 | 0.000036 | 0.000036 | 0.027436 | 0.027436 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 4.1056 | 4.1056 | 242.31 | 242.31 | 69.12 | 69.12 | 2 | 0 | 1.28 | 0.000036 | 0.000036 | 0.034567 | 0.034567 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.7383 | 3.7383 | 124.17 | 69.85 | 54.51 | 54.51 | 1 | 0 | 1.64 | 0.000036 | 0.000036 | 0.018944 | 0.018944 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.8827 | 3.8827 | 124.88 | 124.88 | 56.61 | 56.61 | 1 | 1 | 1.28 | 0.000036 | 0.000036 | 0.023934 | 0.023934 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5932 | 3.5932 | 39.38 | 39.38 | 42.78 | 42.78 | 0 | 0 | 1.28 | 0.000036 | 0.000036 | 0.013574 | 0.013574 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5752 | 3.5752 | 51.94 | 51.94 | 30.10 | 30.10 | 3 | 0 | 1.28 | 0.000036 | 0.000036 | 0.014640 | 0.014640 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6540 | 4.6540 | 831.34 | 831.34 | 137.30 | 137.30 | 0 | 0 | 1.28 | 0.000006 | 0.000006 | 0.053600 | 0.053600 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6217 | 4.6217 | 716.62 | 716.62 | 127.47 | 127.47 | 5 | 0 | 1.28 | 0.000006 | 0.000006 | 0.054428 | 0.054428 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6310 | 4.6310 | 661.21 | 661.21 | 122.45 | 122.45 | 19 | 0 | 1.28 | 0.000006 | 0.000006 | 0.050608 | 0.050608 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6128 | 4.6128 | 585.75 | 585.75 | 115.83 | 115.83 | 11 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051012 | 0.051012 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.4979 | 4.4979 | 442.11 | 442.11 | 100.35 | 100.35 | 11 | 0 | 1.28 | 0.000006 | 0.000006 | 0.051765 | 0.051765 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4296 | 4.4296 | 348.83 | 348.83 | 90.19 | 90.19 | 2 | 0 | 1.28 | 0.000006 | 0.000006 | 0.049628 | 0.049628 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.2730 | 4.2730 | 153.32 | 153.32 | 63.96 | 63.96 | 3 | 0 | 1.28 | 0.000006 | 0.000006 | 0.040202 | 0.040202 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.9292 | 3.9292 | 57.14 | 57.14 | 39.27 | 39.27 | 1 | 0 | 1.28 | 0.000006 | 0.000006 | 0.023659 | 0.023659 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.2707 | 3.2707 | 20.56 | 20.56 | 23.56 | 23.56 | 1 | 0 | 1.28 | 0.000006 | 0.000006 | 0.007671 | 0.007671 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000009** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = $(BR)(R_B)(R_C)(R_{XC})(R_D)$(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 1 | Ship | Bulk Carrier | 210,000 | 0.0000 | 4.4584 | 0.00 | 991.10 | 0.00 | 243.23 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.067016 | 0.067016 | 0.000000 | 0.032081 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 2 | Ship | Bulk Carrier | 205,000 | 0.0000 | 4.4584 | 0.00 | 1163.65 | 0.00 | 240.31 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.067016 | 0.067016 | 0.000000 | 0.031123 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 3 | Ship | Bulk Carrier | 185,000 | 0.0000 | 4.4212 | 0.00 | 1047.00 | 0.00 | 226.38 | 0 | 3 | 1.28 | 0.000028 | 0.000028 | 0.062814 | 0.062814 | 0.000000 | 0.026201 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 4 | Ship | Bulk Carrier | 180,000 | 0.0000 | 4.4212 | 0.00 | 1073.12 | 0.00 | 223.30 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.062814 | 0.062814 | 0.000000 | 0.025030 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 5 | Ship | Bulk Carrier | 175,000 | 0.0000 | 4.4158 | 0.00 | 902.72 | 0.00 | 219.91 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062984 | 0.062984 | 0.000000 | 0.023702 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 6 | Ship | Bulk Carrier | 170,000 | 0.0000 | 4.4139 | 0.00 | 983.92 | 0.00 | 216.66 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.062090 | 0.062090 | 0.000000 | 0.022389 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 7 | Ship | Bulk Carrier | 165,000 | 0.0000 | 4.4139 | 0.00 | 965.00 | 0.00 | 213.45 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062090 | 0.062090 | 0.000000 | 0.021054 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 8 | Ship | Bulk Carrier | 155,000 | 0.0000 | 4.2057 | 0.00 | 819.08 | 0.00 | 197.12 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.064700 | 0.064700 | 0.000000 | 0.013594 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 9 | Ship | Bulk Carrier | 150,000 | 0.0000 | 4.1757 | 0.00 | 806.97 | 0.00 | 192.53 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061960 | 0.061960 | 0.000000 | 0.011270 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 10 | Ship | Tanker | 120,000 | 0.0000 | 3.7451 | 0.00 | 424.33 | 0.00 | 154.45 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 11 | Ship | Bulk Carrier | 120,000 | 0.0000 | 4.1451 | 0.00 | 451.03 | 0.00 | 170.94 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 12 | Ship | Container | 120,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.063374 | 0.063374 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 13 | Ship | Tanker | 115,000 | 0.0000 | 3.7451 | 0.00 | 541.73 | 0.00 | 151.19 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.002008 | 0.063263 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 14 | Ship | Bulk Carrier | 115,000 | 0.0000 | 4.1451 | 0.00 | 506.67 | 0.00 | 167.34 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062275 | 0.062275 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 15 | Ship | Container | 115,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.065140 | 0.065140 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 16 | Ship | Tanker | 110,000 | 0.0000 | 3.7274 | 0.00 | 416.75 | 0.00 | 147.17 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.001868 | 0.063170 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 17 | Ship | Bulk Carrier | 110,000 | 0.0000 | 4.1473 | 0.00 | 522.79 | 0.00 | 163.75 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062266 | 0.062266 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 18 | Ship | Container | 110,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058063 | 0.058063 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 19 | Ship | Tanker | 105,000 | 0.0000 | 3.7347 | 0.00 | 415.65 | 0.00 | 144.07 | 0 | 0 | 10.20 | 0.000015 | 0.000028 | 0.001837 | 0.061299 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 20 | Ship | Bulk Carrier | 105,000 | 0.0000 | 4.1000 | 0.00 | 501.34 | 0.00 | 158.16 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.062070 | 0.062070 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 21 | Ship | Container | 105,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057986 | 0.057986 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 22 | Ship | Bulk Carrier | 100,000 | 0.0000 | 4.1000 | 0.00 | 389.78 | 0.00 | 154.35 | 0 | 1 | 1.28 | 0.000028 | 0.000028 | 0.057246 | 0.057246 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 23 | Ship | Container | 100,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.060442 | 0.060442 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 24 | Ship | Bulk Carrier | 95,000 | 0.0000 | 4.0840 | 0.00 | 495.49 | 0.00 | 149.85 | 0 | 2 | 1.28 | 0.000028 | 0.000028 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 25 | Ship | Container | 95,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.061855 | 0.061855 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 26 | Ship | Bulk Carrier | 90,000 | 0.0000 | 4.0840 | 0.00 | 454.78 | 0.00 | 145.86 | 0 | 2 | 1.28 | 0.000028 | 0.000028 | 0.057017 | 0.057017 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 27 | Ship | Bulk Carrier | 85,000 | 0.0000 | 4.0840 | 0.00 | 357.33 | 0.00 | 141.75 | 0 | 17 | 1.28 | 0.000028 | 0.000028 | 0.051251 | 0.051251 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 28 | Ship | Container | 85,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.057638 | 0.057638 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 29 | Ship | Bulk Carrier | 80,000 | 0.0000 | 4.0727 | 0.00 | 306.68 | 0.00 | 137.14 | 0 | 12 | 1.28 | 0.000028 | 0.000028 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 30 | Ship | Container | 80,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.059514 | 0.059514 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 31 | Ship | Tanker | 75,000 | 0.0000 | 4.4586 | 0.00 | 443.79 | 0.00 | 145.36 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001311 | 0.052648 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 32 | Ship | Bulk Carrier | 75,000 | 0.0000 | 4.0727 | 0.00 | 313.41 | 0.00 | 132.78 | 0 | 5 | 1.28 | 0.000028 | 0.000028 | 0.051064 | 0.051064 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 33 | Ship | Container | 75,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058034 | 0.058034 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 34 | Ship | Tanker | 70,000 | 0.0000 | 4.4586 | 0.00 | 343.05 | 0.00 | 140.43 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001261 | 0.051208 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 35 | Ship | Bulk Carrier | 70,000 | 0.0000 | 3.9866 | 0.00 | 239.71 | 0.00 | 125.57 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.052334 | 0.052334 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 36 | Ship | Container | 70,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.058442 | 0.058442 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 37 | Ship | Tanker | 65,000 | 0.0000 | 4.4062 | 0.00 | 322.70 | 0.00 | 133.73 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.001103 | 0.050324 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 38 | Ship | Bulk Carrier | 65,000 | 0.0000 | 3.9904 | 0.00 | 245.52 | 0.00 | 121.11 | 0 | 15 | 1.28 | 0.000028 | 0.000028 | 0.048809 | 0.048809 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 39 | Ship | Container | 65,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.056539 | 0.056539 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 40 | Ship | Bulk Carrier | 60,000 | 0.0000 | 3.9502 | 0.00 | 225.94 | 0.00 | 115.19 | 0 | 11 | 1.28 | 0.000028 | 0.000028 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 41 | Ship | General Cargo | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.049727 | 0.049727 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 42 | Ship | Container | 60,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.054292 | 0.054292 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 43 | Ship | Tanker | 55,000 | 0.0000 | 4.2616 | 0.00 | 330.67 | 0.00 | 118.98 | 0 | 1 | 1.64 | 0.000015 | 0.000028 | 0.000761 | 0.046097 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 44 | Ship | Bulk Carrier | 55,000 | 0.0000 | 4.2949 | 0.00 | 261.67 | 0.00 | 119.91 | 0 | 3 | 1.28 | 0.000028 | 0.000028 | 0.047252 | 0.047252 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 45 | Ship | General Cargo | 55,000 | 4.3451 | 4.3451 | 425.15 | 425.15 | 121.31 | 121.31 | 3 | 0 | 1.28 | 0.000028 | 0.000028 | 0.048809 | 0.048809 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 46 | Ship | Tanker | 50,000 | 0.0000 | 4.2558 | 0.00 | 321.40 | 0.00 | 113.29 | 0 | 3 | 1.64 | 0.000015 | 0.000028 | 0.000750 | 0.045886 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 47 | Ship | Bulk Carrier | 50,000 | 0.0000 | 4.3054 | 0.00 | 280.36 | 0.00 | 114.61 | 0 | 2 | 1.28 | 0.000028 | 0.000028 | 0.047599 | 0.047599 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 48 | Ship | General Cargo | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047892 | 0.047892 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 49 | Ship | Container | 50,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.051584 | 0.051584 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |

# ANNUAL FREQUENCY OF COLLAPSE COMPUTATIONS

**Pier ID:** 2
**Description:** South Tower
**Vessel Direction:** Outbound
**Channel Leg:** 6

| Vessel ID | Vessel Type | Description | Single Vessel DWT (tonnes) | Impact Speed at Pier, V (m/sec) [1] | | Collision Energy, KE (MN-m) | | Maximum Impact Force at Pier, P (MN) [1] | | Vessel Frequency, N [1] | | Vessel Trip Growth Factor, GF | Probability of Aberrancy, PA [2] | | Geometric Probability, PG [3] | | Probability of Collapse, PC [4] | | Protection Factor, PF | Annual Frequency of Collapse, AF [5] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Loaded | Ballasted | Loaded | Ballasted | | Loaded | Ballasted | Total |
| 50 | Ship | Tanker | 45,000 | 0.0000 | 4.2440 | 0.00 | 346.03 | 0.00 | 107.18 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.000728 | 0.045451 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 51 | Ship | Bulk Carrier | 45,000 | 0.0000 | 4.2841 | 0.00 | 225.66 | 0.00 | 108.19 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.044239 | 0.044239 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 52 | Ship | General Cargo | 45,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.044059 | 0.044059 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 53 | Ship | Tanker | 40,000 | 0.0000 | 4.2318 | 0.00 | 229.96 | 0.00 | 100.76 | 0 | 0 | 1.64 | 0.000015 | 0.000028 | 0.000630 | 0.041601 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 54 | Ship | Bulk Carrier | 40,000 | 0.0000 | 4.2379 | 0.00 | 207.82 | 0.00 | 100.90 | 0 | 6 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 55 | Ship | General Cargo | 40,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 56 | Ship | Tanker | 35,000 | 0.0000 | 4.1933 | 0.00 | 198.84 | 0.00 | 93.39 | 0 | 1 | 1.64 | 0.000028 | 0.000028 | 0.039387 | 0.039387 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 57 | Ship | Bulk Carrier | 35,000 | 0.0000 | 4.2379 | 0.00 | 198.20 | 0.00 | 94.39 | 0 | 6 | 1.28 | 0.000028 | 0.000028 | 0.043520 | 0.043520 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 58 | Ship | General Cargo | 35,000 | 4.2379 | 4.2379 | 235.58 | 235.58 | 94.39 | 94.39 | 11 | 4 | 1.28 | 0.000028 | 0.000028 | 0.041816 | 0.041816 | 1.000000 | 1.000000 | 0.1400 | 0.000002 | 0.000001 | 0.000003 |
| 59 | Ship | Container | 35,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.047991 | 0.047991 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 60 | Ship | Tanker | 30,000 | 0.0000 | 4.0894 | 0.00 | 150.31 | 0.00 | 84.32 | 0 | 1 | 1.64 | 0.000028 | 0.000028 | 0.035441 | 0.035441 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 61 | Ship | Bulk Carrier | 30,000 | 0.0000 | 4.1728 | 0.00 | 145.07 | 0.00 | 86.04 | 0 | 3 | 1.28 | 0.000028 | 0.000028 | 0.038633 | 0.038633 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 62 | Ship | General Cargo | 30,000 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.037551 | 0.037551 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 63 | Ship | Articulated Tug/Barge | 30,000 | 0.0000 | 4.3897 | 0.00 | 176.63 | 0.00 | 90.51 | 0 | 3 | 1.28 | 0.000028 | 0.000028 | 0.041149 | 0.041149 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 64 | Ship | Tanker | 25,000 | 0.0000 | 3.9703 | 0.00 | 113.71 | 0.00 | 74.73 | 0 | 0 | 1.64 | 0.000028 | 0.000028 | 0.028823 | 0.028823 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 65 | Ship | Bulk Carrier | 25,000 | 4.0466 | 4.0466 | 228.91 | 146.40 | 76.17 | 76.17 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033052 | 0.033052 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 66 | Ship | General Cargo | 25,000 | 4.0466 | 4.0466 | 225.68 | 225.68 | 76.17 | 76.17 | 1 | 0 | 1.28 | 0.000028 | 0.000028 | 0.033052 | 0.033052 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 67 | Ship | Articulated Tug/Barge | 25,000 | 4.2616 | 4.2616 | 296.14 | 149.88 | 80.22 | 80.22 | 2 | 2 | 1.28 | 0.000028 | 0.000028 | 0.039156 | 0.039156 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 68 | Ship | Tanker | 20,000 | 3.9600 | 3.9600 | 204.65 | 100.77 | 66.67 | 66.67 | 4 | 9 | 1.64 | 0.000028 | 0.000028 | 0.028446 | 0.028446 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 69 | Ship | Bulk Carrier | 20,000 | 3.9496 | 3.9496 | 178.15 | 101.96 | 66.49 | 66.49 | 2 | 10 | 1.28 | 0.000028 | 0.000028 | 0.027436 | 0.027436 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 70 | Ship | General Cargo | 20,000 | 4.1056 | 4.1056 | 242.31 | 242.31 | 69.12 | 69.12 | 2 | 0 | 1.28 | 0.000028 | 0.000028 | 0.034567 | 0.034567 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 71 | Ship | Tanker | 15,000 | 3.7383 | 3.7383 | 124.17 | 69.85 | 54.51 | 54.51 | 1 | 0 | 1.64 | 0.000028 | 0.000028 | 0.018944 | 0.018944 | 0.000000 | 0.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 72 | Ship | General Cargo | 15,000 | 3.8827 | 3.8827 | 124.88 | 124.88 | 56.61 | 56.61 | 1 | 1 | 1.28 | 0.000028 | 0.000028 | 0.023934 | 0.023934 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 73 | Ship | General Cargo | 10,000 | 3.5932 | 3.5932 | 39.38 | 39.38 | 42.78 | 42.78 | 0 | 0 | 1.28 | 0.000028 | 0.000028 | 0.013574 | 0.013574 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 74 | Ship | General Cargo | 5,000 | 3.5752 | 3.5752 | 51.94 | 51.94 | 30.10 | 30.10 | 3 | 0 | 1.28 | 0.000028 | 0.000028 | 0.014640 | 0.014640 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 75 | Ship | Cruise Ship (GT=121,900) | 61,410 | 4.6540 | 4.6540 | 831.34 | 831.34 | 137.30 | 137.30 | 0 | 0 | 1.28 | 0.000005 | 0.000005 | 0.053600 | 0.053600 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 76 | Ship | Cruise Ship (GT=113,600) | 53,680 | 4.6217 | 4.6217 | 716.62 | 716.62 | 127.47 | 127.47 | 5 | 0 | 1.28 | 0.000005 | 0.000005 | 0.054428 | 0.054428 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 77 | Ship | Cruise Ship (GT=93,500) | 49,330 | 4.6310 | 4.6310 | 661.21 | 661.21 | 122.45 | 122.45 | 19 | 0 | 1.28 | 0.000005 | 0.000005 | 0.050608 | 0.050608 | 1.000000 | 1.000000 | 0.1400 | 0.000001 | 0.000000 | 0.000001 |
| 78 | Ship | Cruise Ship (GT=86,300) | 44,490 | 4.6128 | 4.6128 | 585.75 | 585.75 | 115.83 | 115.83 | 11 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051012 | 0.051012 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 79 | Ship | Cruise Ship (GT=78,300) | 35,120 | 4.4979 | 4.4979 | 442.11 | 442.11 | 100.35 | 100.35 | 11 | 0 | 1.28 | 0.000005 | 0.000005 | 0.051765 | 0.051765 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 80 | Ship | Cruise Ship (GT=55,800) | 29,250 | 4.4296 | 4.4296 | 348.83 | 348.83 | 90.19 | 90.19 | 2 | 0 | 1.28 | 0.000005 | 0.000005 | 0.049628 | 0.049628 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 81 | Ship | Cruise Ship (GT=30,300) | 15,810 | 4.2730 | 4.2730 | 153.32 | 153.32 | 63.96 | 63.96 | 3 | 0 | 1.28 | 0.000005 | 0.000005 | 0.040202 | 0.040202 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 82 | Ship | Cruise Ship (GT=11,000) | 7,050 | 3.9292 | 3.9292 | 57.14 | 57.14 | 39.27 | 39.27 | 1 | 0 | 1.28 | 0.000005 | 0.000005 | 0.023659 | 0.023659 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| 83 | Ship | Cruise Ship (GT=5,300) | 3,660 | 3.2707 | 3.2707 | 20.56 | 20.56 | 23.56 | 23.56 | 1 | 0 | 1.28 | 0.000005 | 0.000005 | 0.007671 | 0.007671 | 1.000000 | 1.000000 | 0.1400 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | | | | | | | | | | | | | | | | **Total for Pier:** | **0.000007** |

**Notes:**

[1] A value of 0 under "Vessel Frequency" indicates that either there are no vessel trips documented or the vessel has run aground, therefore causing the "Impact Speed at Pier" and "Maximum Impact Force at Pier" to also be a 0 value

[2] PA = (BR)($R_B$)($R_C$)($R_{XC}$)($R_D$)(Assigned Aberrancy Distribution for Each Leg & Vessel Direction)

[3] Normal distribution for the Geometric Probability (PG) is centered on the centerline of vessel transit path at each defined transit path leg

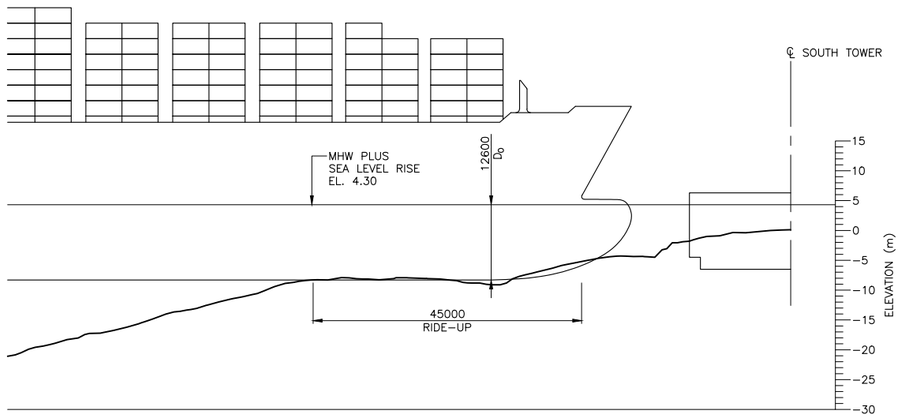
[4] Probability of Collapse (PC) is based on the ratio of bridge ultimate lateral capacity (H) to vessel impact force (P)

[5] AF = (N)(GF)(PA)(PG)(PC)(PF)

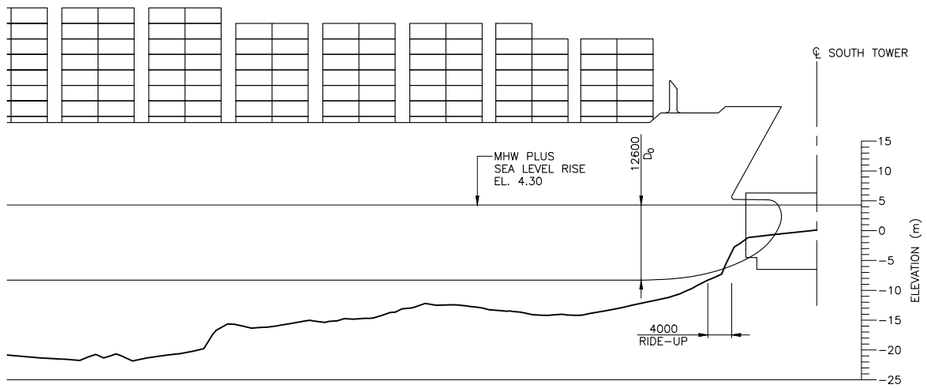
# APPENDIX

# B VESSEL RIDE-UP ANALYSIS

# APPENDIX




SOUTH TOWER ELEVATION AT 19°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 22°
(LOADED)
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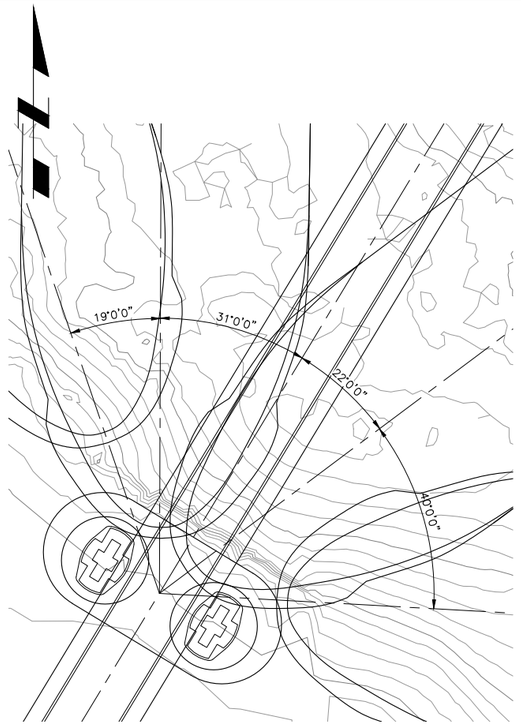
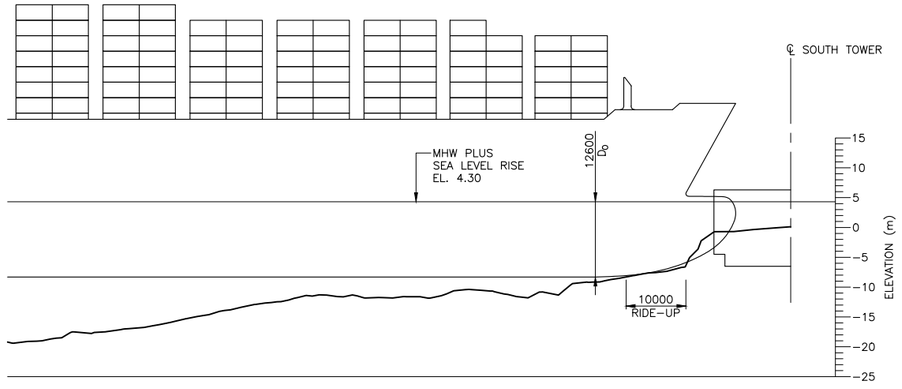



SOUTH TOWER PLAN
SCALE: 1:500




SOUTH TOWER ELEVATION AT 31°
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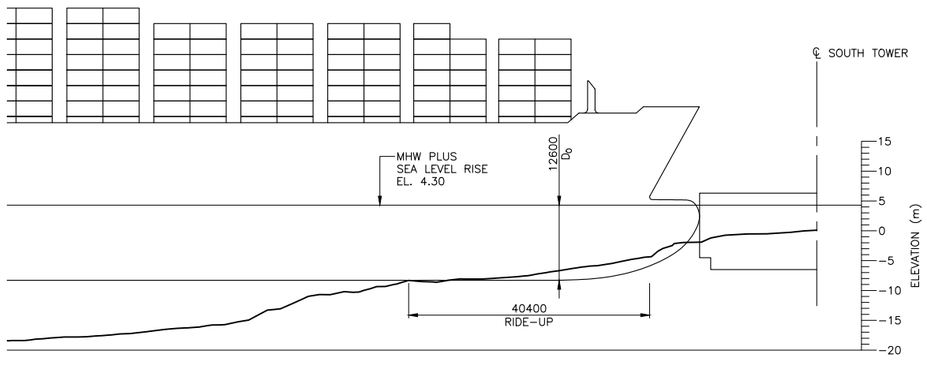


SOUTH TOWER ELEVATION AT 40°
(LOADED)
SCALE: 1:500

VESSEL ID #12 (CONTAINER)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 210,000 tonnes |
| LENGTH OVERALL(LOA): | 300m |
| BREADTH/BEAM: | 50m |
| DRAFT($D_0$): | 12.6m |
| DRAFT($D_{EB}$): | 12.6m |

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

MMM GROUP

| Rev | Date | Description | Init |
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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
SOUTH TOWER
VESSEL SCENARIOS – V12

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

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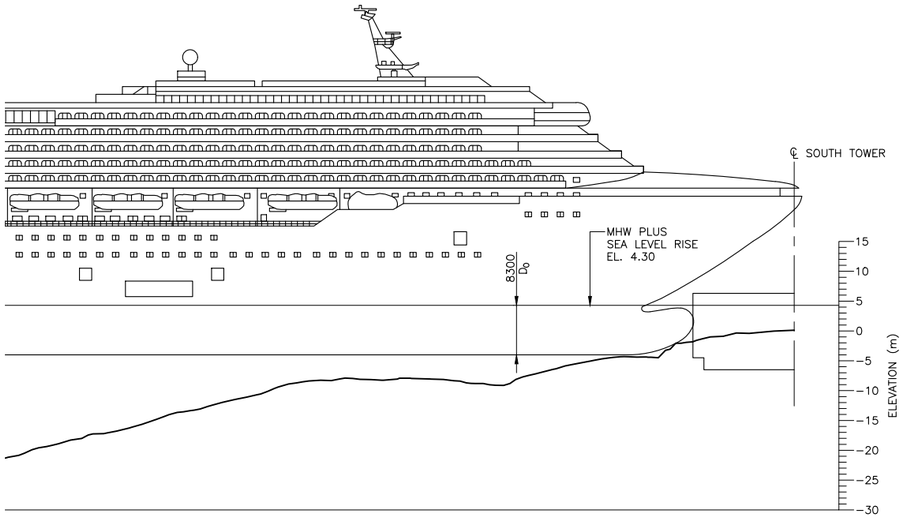
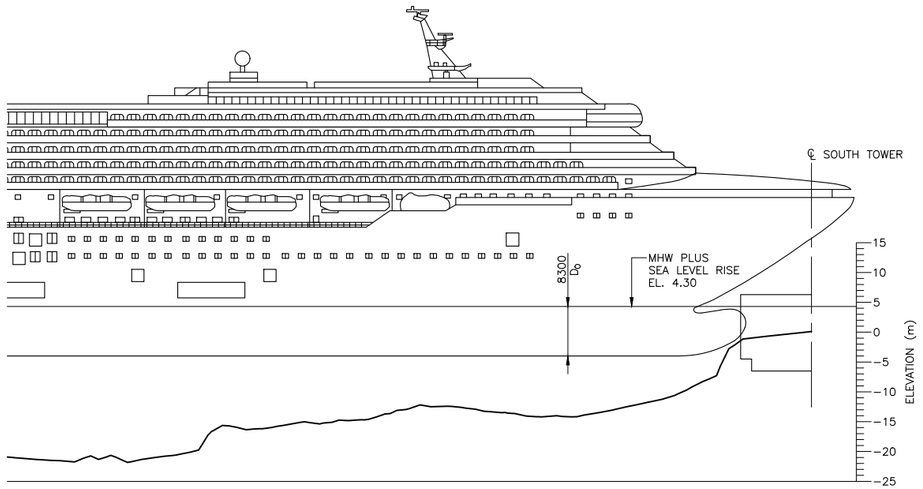
|---|---|---|---|
| | 83118 | . | 01481–B101 |

CANCEL PRINTS BEARING PREVIOUS LETTER

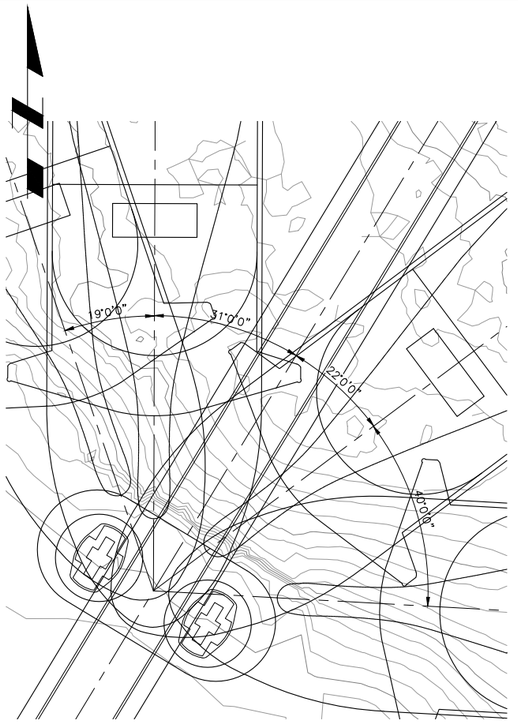
H-308;1=1-(07-08)



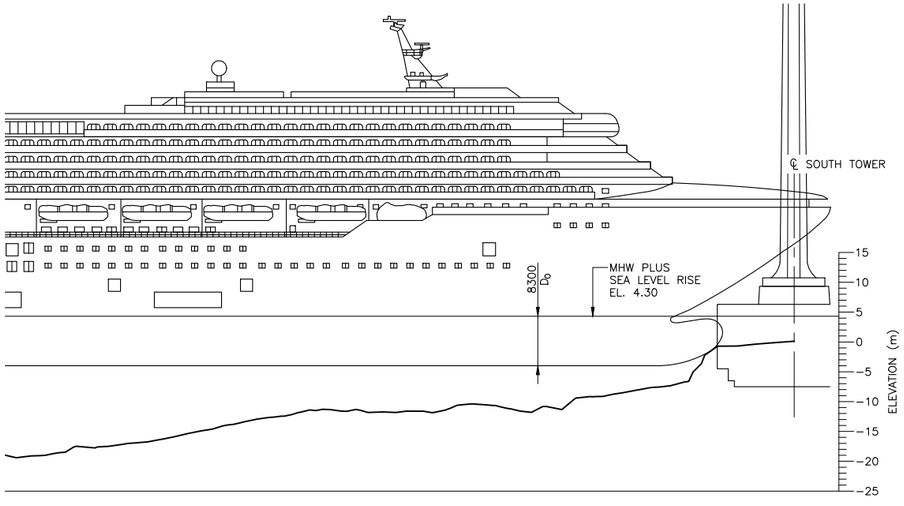

SOUTH TOWER ELEVATION AT 19°
(LOADED)
SCALE: 1:500



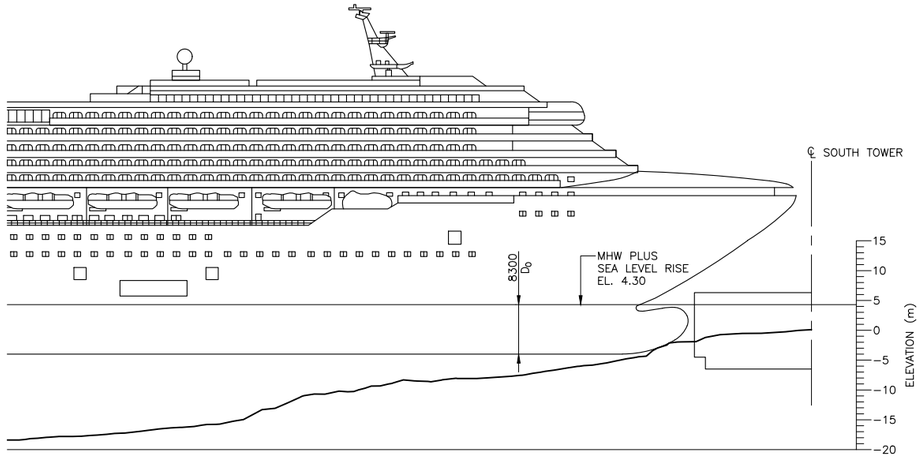

SOUTH TOWER ELEVATION AT 22°
(LOADED)
SCALE: 1:500




SOUTH TOWER PLAN
SCALE: 1:500




SOUTH TOWER ELEVATION AT 31°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 40°
(LOADED)
SCALE: 1:500

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

VESSEL ID #75 (CRUISE SHIP)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 61,410 tonnes |
| LENGTH OVERALL(LOA): | 317m |
| BREADTH/BEAM: | 37m |
| DRAFT($D_0$): | 8.3m |
| DRAFT($D_{EB}$): | 8.3m |

MMM GROUP

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Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
SOUTH TOWER
VESSEL SCENARIOS – V75

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
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| | 83118 | . | 01481–B102 |

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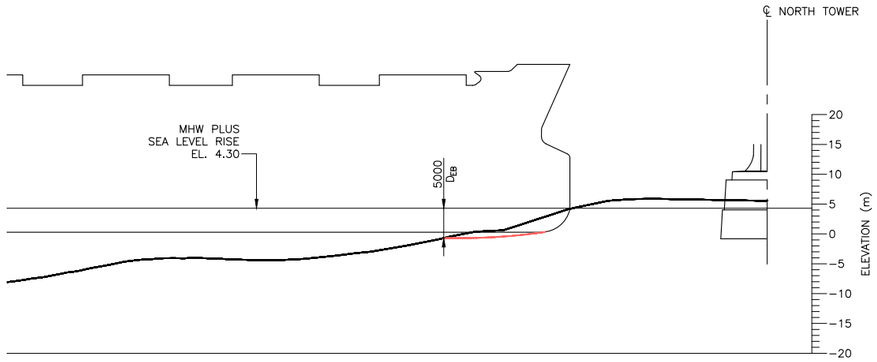
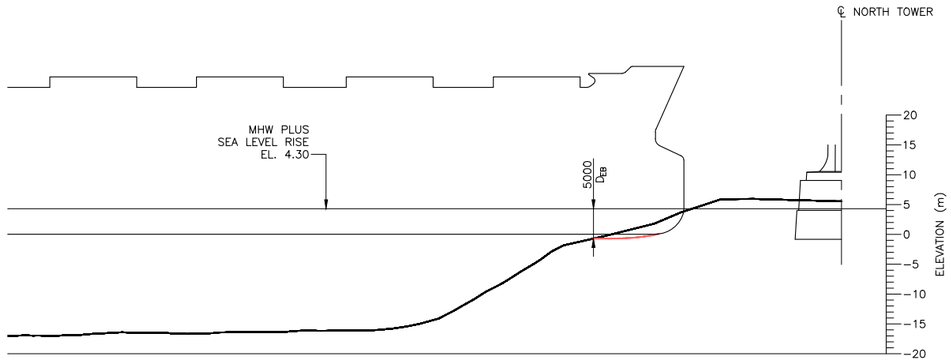
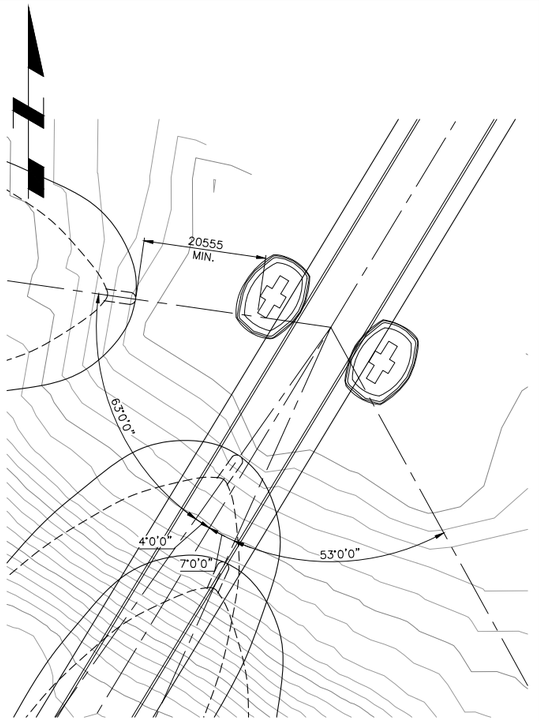
11-508-11-2(07-08)



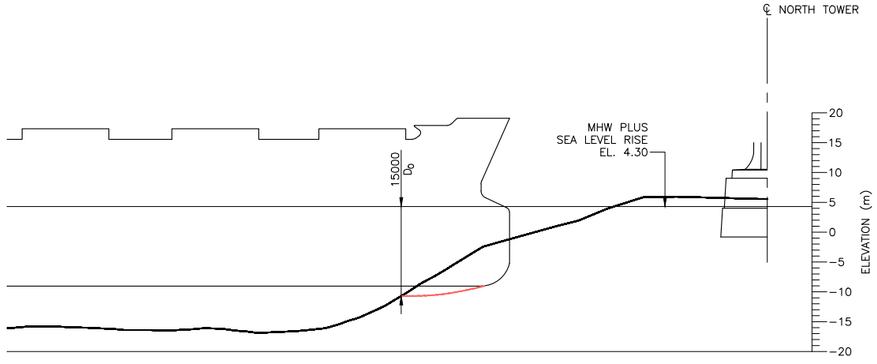

NORTH TOWER ELEVATION AT 63°
(BALLASTED)
SCALE: 1:500



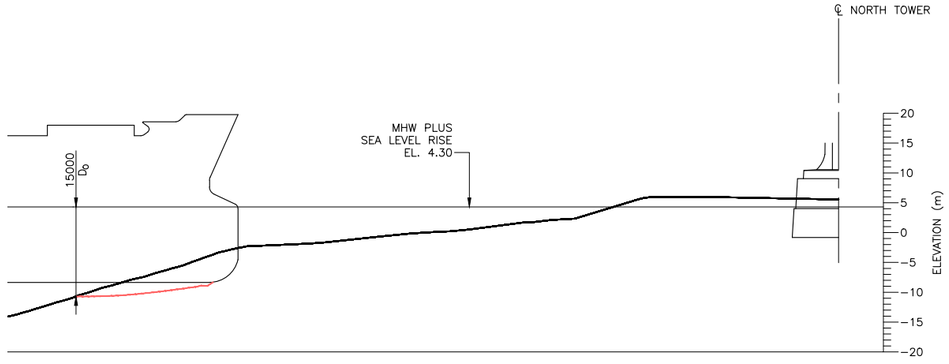

NORTH TOWER ELEVATION AT 4°
(BALLASTED)
SCALE: 1:500




NORTH TOWER PLAN
SCALE: 1:500




NORTH TOWER ELEVATION AT 7°
(LOADED)
SCALE: 1:500




NORTH TOWER ELEVATION AT 53°
(LOADED)
SCALE: 1:500

VESSEL ID #01 (BULKER)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 210,000 tonnes |
| LENGTH OVERALL(LOA): | 300m |
| BREADTH/BEAM: | 50m |
| DRAFT($D_0$): | 15.0m |
| DRAFT($D_{EB}$): | 5.0m |

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

NOTE:

1. NORTH TOWER PEDESTAL SHOWN PERPENDICULAR FOR REFERENCE PURPOSES ONLY.

MMM GROUP

| Rev | Date | Description | Init |
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BRITISH COLUMBIA | Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
NORTH TOWER
VESSEL SCENARIOS – V01

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
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FILE No. | PROJECT No. 83118 | REG. . | DRAWING No. 01481–B201

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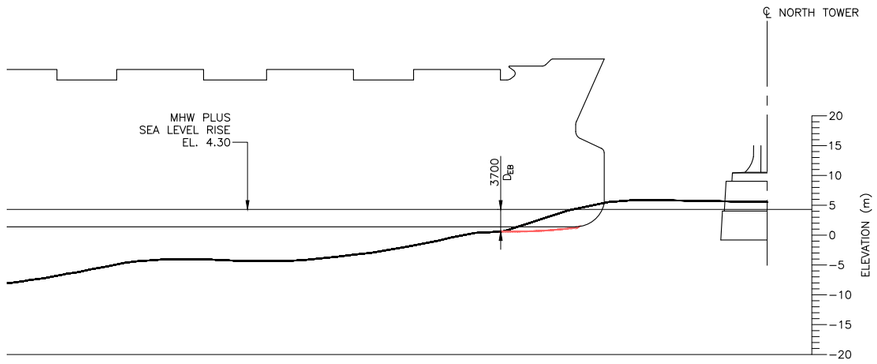
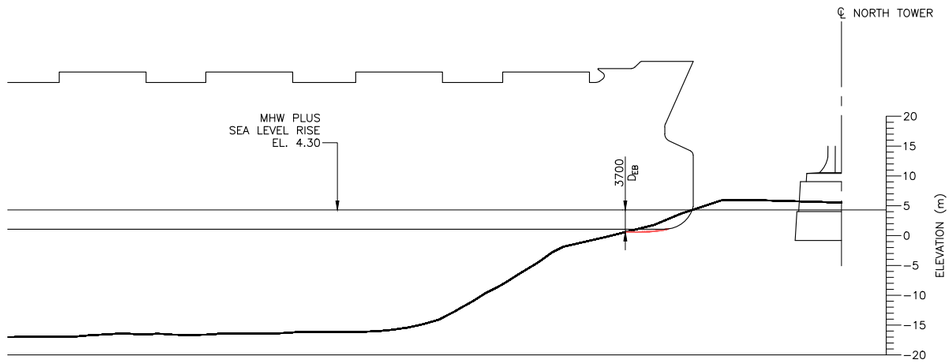
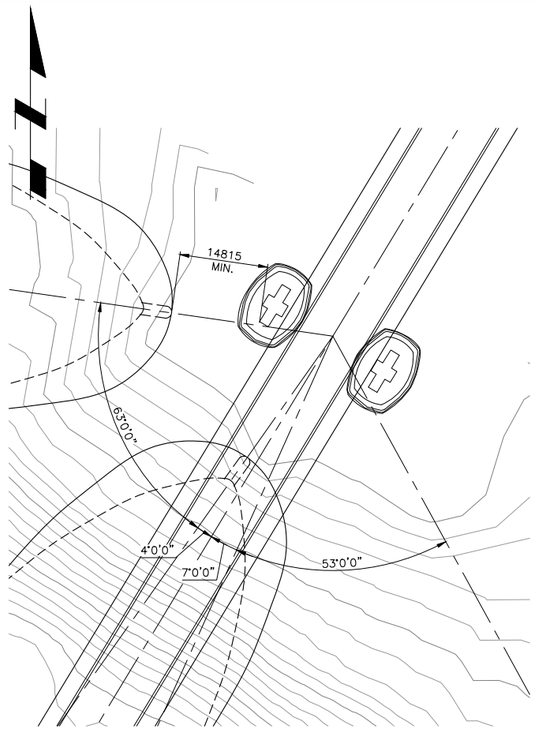



NORTH TOWER ELEVATION AT 63°
(BALLASTED)
SCALE: 1:500




NORTH TOWER ELEVATION AT 4°
(BALLASTED)
SCALE: 1:500




NORTH TOWER PLAN
SCALE: 1:500

| VESSEL ID #35 (BULKER) | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 70,000 tonnes |
| LENGTH OVERALL(LOA): | 199m |
| BREADTH/BEAM: | 36m |
| DRAFT($D_O$): | 12.2m |
| DRAFT($D_{EB}$): | 3.7m |

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

NOTE:

1. NORTH TOWER PEDESTAL SHOWN PERPENDICULAR FOR REFERENCE PURPOSES ONLY.

MMM GROUP

| Rev | Date | Description | Init |
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VESSEL COLLISION RISK MITIGATION STUDY
NORTH TOWER
VESSEL SCENARIOS – V35

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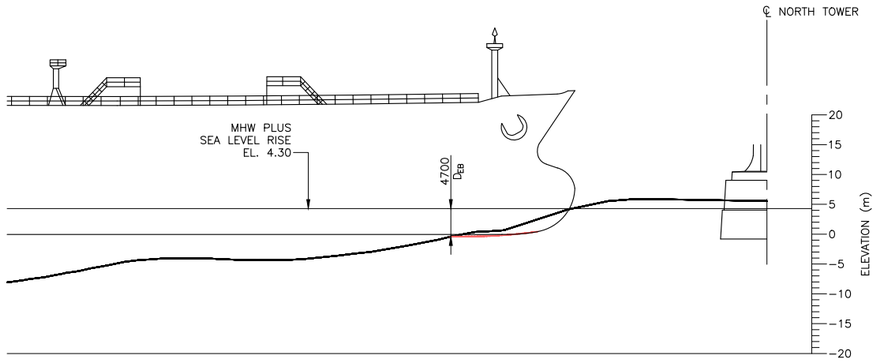
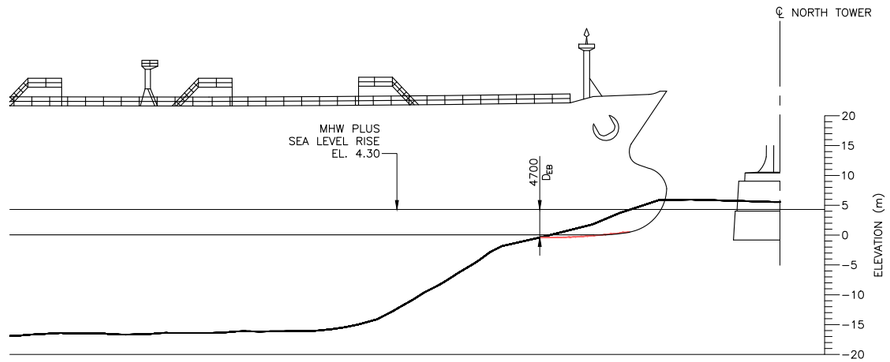
PROJECT No. 83118
REG. .
DRAWING No. 01481–B202

CANCEL PRINTS BEARING PREVIOUS LETTER

H-308-r1-(07-08)




NORTH TOWER ELEVATION AT 63°
(BALLASTED)
SCALE: 1:500




NORTH TOWER ELEVATION AT 4°
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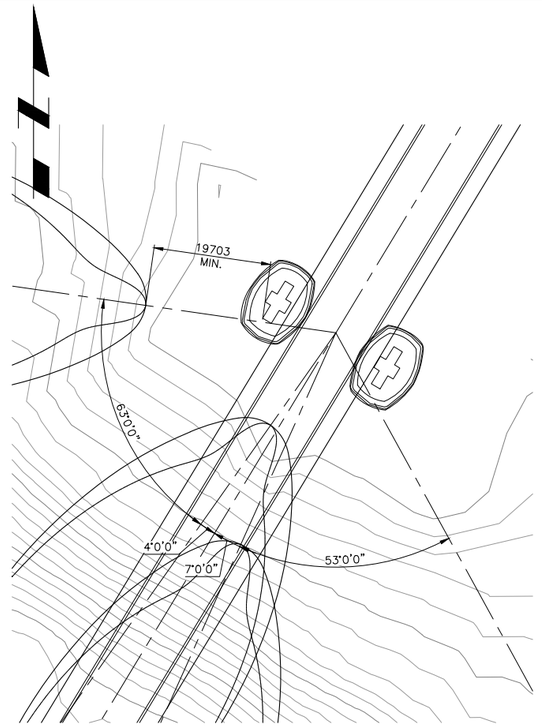
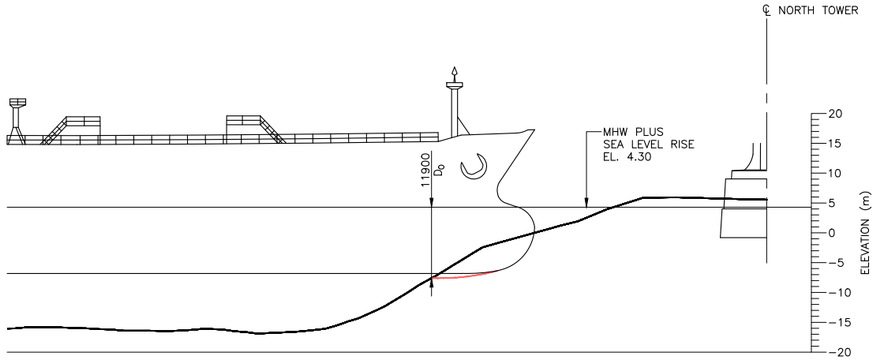
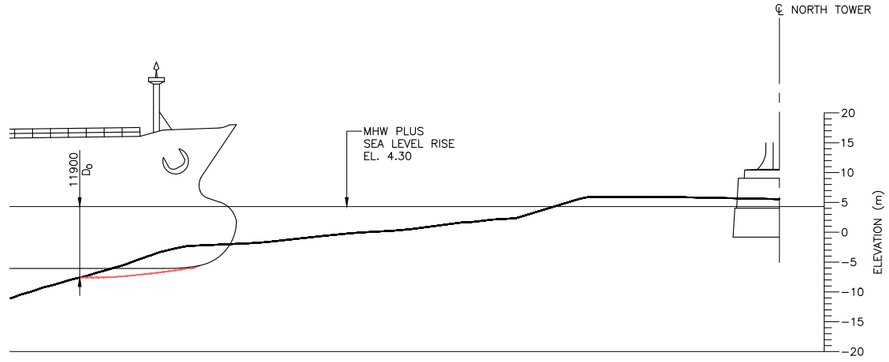



NORTH TOWER PLAN
SCALE: 1:500




NORTH TOWER ELEVATION AT 7°
(LOADED)
SCALE: 1:500




NORTH TOWER ELEVATION AT 53°
(LOADED)
SCALE: 1:500

| VESSEL ID #10 (TANKER) | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 120,000 tonnes |
| LENGTH OVERALL(LOA): | 250m |
| BREADTH/BEAM: | 44m |
| DRAFT($D_0$): | 11.9m |
| DRAFT($D_{EB}$): | 4.7m |

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

NOTE:

1. NORTH TOWER PEDESTAL SHOWN PERPENDICULAR FOR REFERENCE PURPOSES ONLY.

MMM GROUP

| Rev | Date | Description | Init |
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01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
NORTH TOWER
VESSEL SCENARIOS – V10

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CANCEL PRINTS BEARING PREVIOUS LETTER

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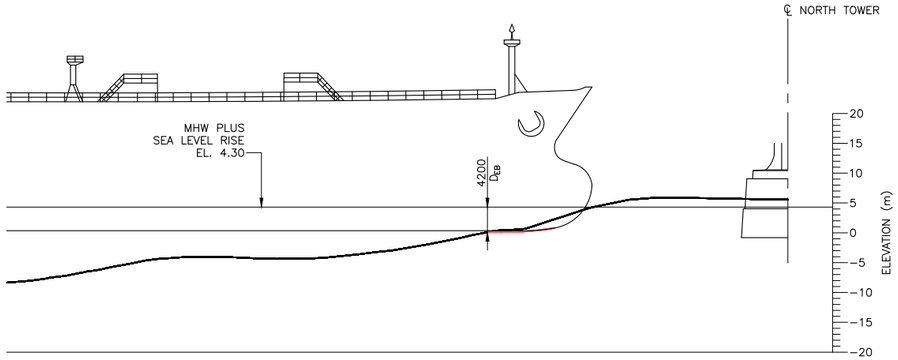


NORTH TOWER ELEVATION AT 63°
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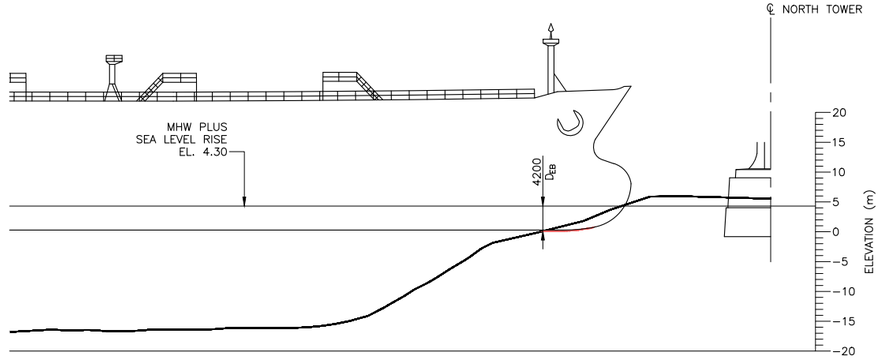
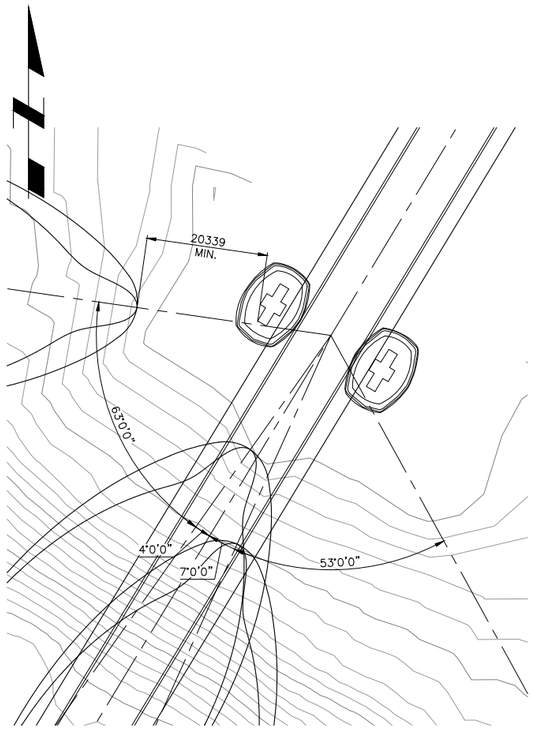
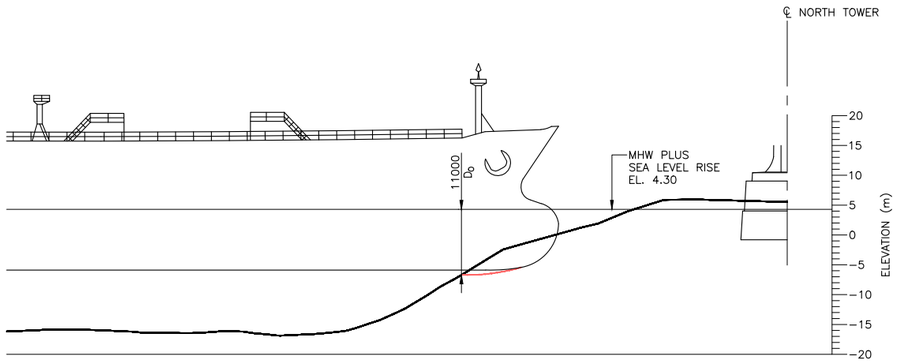


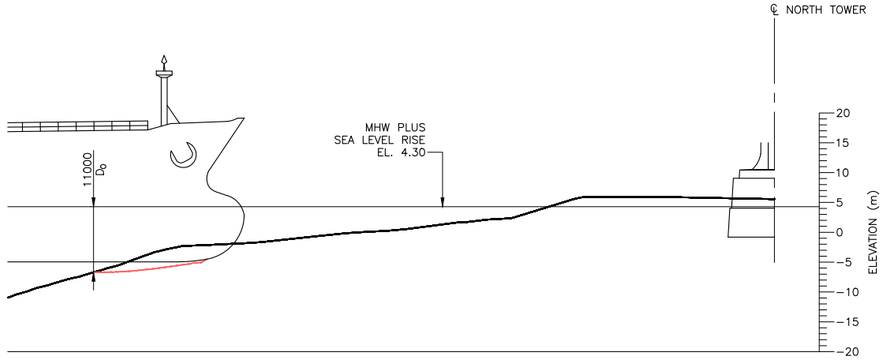

NORTH TOWER ELEVATION AT 4°
(BALLASTED)
SCALE: 1:500




NORTH TOWER PLAN
SCALE: 1:500




NORTH TOWER ELEVATION AT 7°
(LOADED)
SCALE: 1:500




NORTH TOWER ELEVATION AT 53°
(LOADED)
SCALE: 1:500

## VESSEL ID #34 (TANKER)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 70,000 tonnes |
| LENGTH OVERALL(LOA): | 228m |
| BREADTH/BEAM: | 32m |
| DRAFT($D_0$): | 11.0m |
| DRAFT($D_{EB}$): | 4.2m |

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

NOTE:

1. NORTH TOWER PEDESTAL SHOWN PERPENDICULAR FOR REFERENCE PURPOSES ONLY.

MMM GROUP

| Rev | Date | Description | Init |
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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
NORTH TOWER
VESSEL SCENARIOS – V34

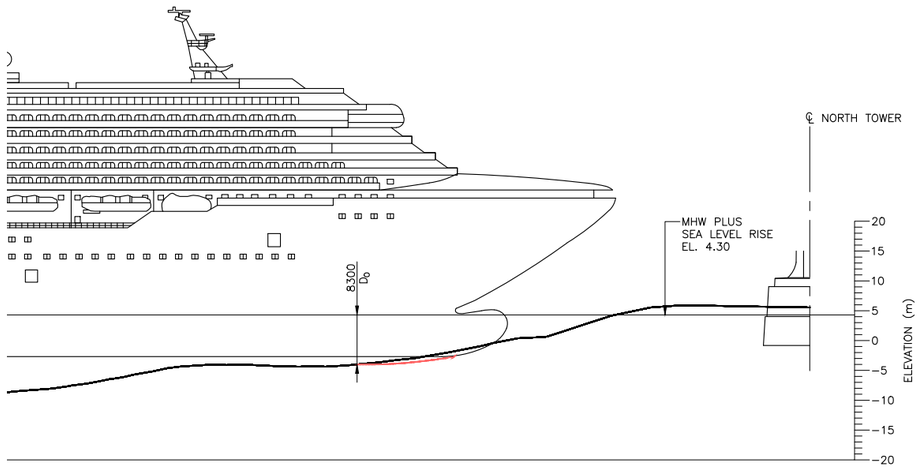
PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

DESIGNED . DATE
CHECKED . DATE
DRAWN SH DATE
SCALE
NEGATIVE No.

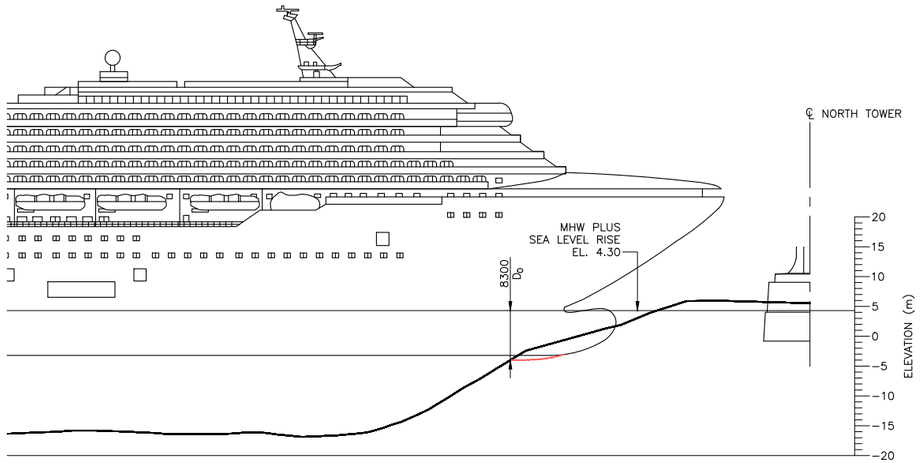
FILE No. | PROJECT No. 83118 | REG. . | DRAWING No. 01481–B204

CANCEL PRINTS BEARING PREVIOUS LETTER

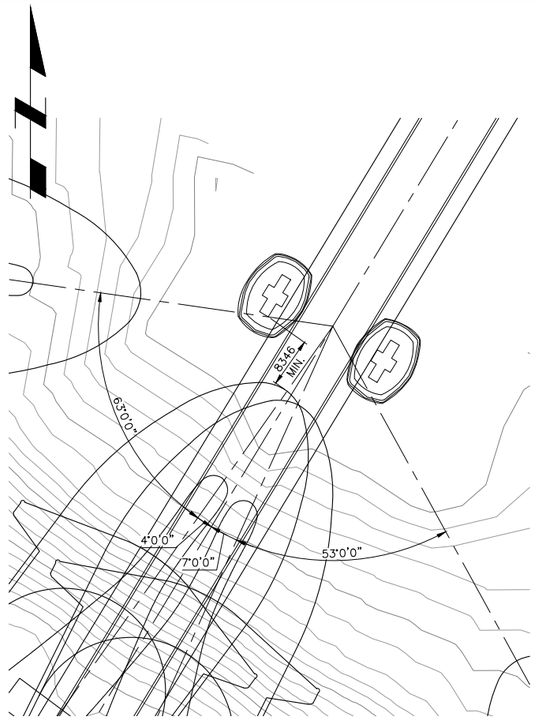
H-308;r1-r(07-08)



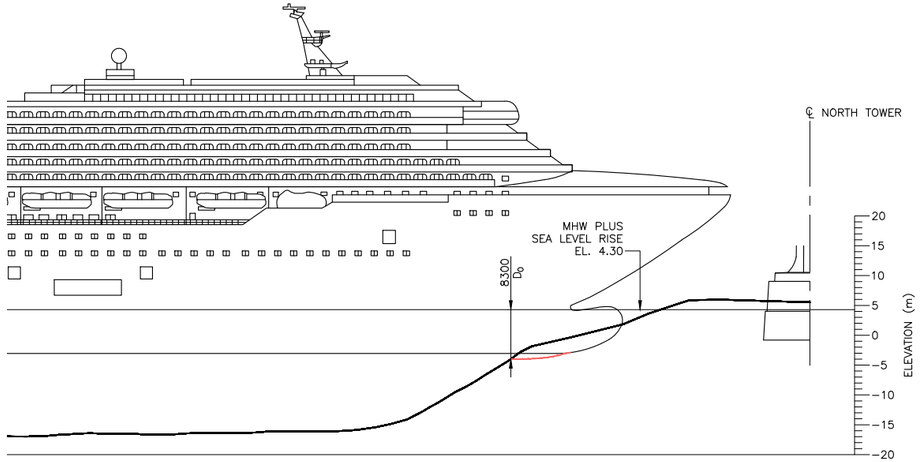

NORTH TOWER ELEVATION AT 63°
(LOADED)
SCALE: 1:500



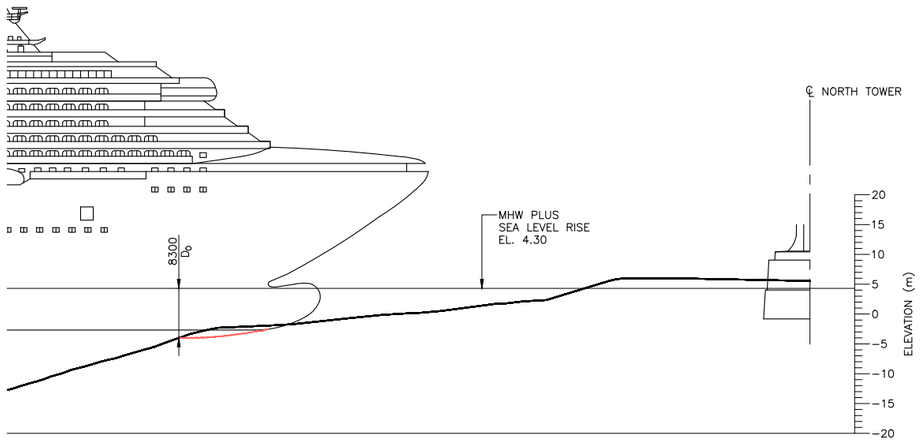

NORTH TOWER ELEVATION AT 7°
(LOADED)
SCALE: 1:500




NORTH TOWER PLAN
SCALE: 1:500




NORTH TOWER ELEVATION AT 4°
(LOADED)
SCALE: 1:500




NORTH TOWER ELEVATION AT 53°
(LOADED)
SCALE: 1:500

VESSEL ID #75 (CRUISE SHIP)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 61,410 tonnes |
| LENGTH OVERALL(LOA): | 317m |
| BREADTH/BEAM: | 37m |
| DRAFT($D_0$): | 8.3m |
| DRAFT($D_{EB}$): | 8.3m |

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

NOTE:

1. NORTH TOWER PEDESTAL SHOWN PERPENDICULAR FOR REFERENCE PURPOSES ONLY.

MMM GROUP

| Rev | Date | Description | Init |
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REVISIONS

BRITISH COLUMBIA | Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
NORTH TOWER
VESSEL SCENARIOS – V75

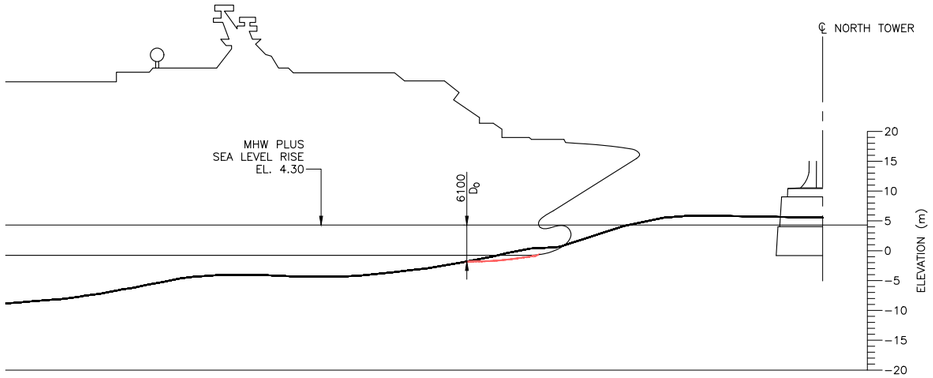
PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

DESIGNED . DATE
CHECKED . DATE
DRAWN SH DATE
SCALE
NEGATIVE No.

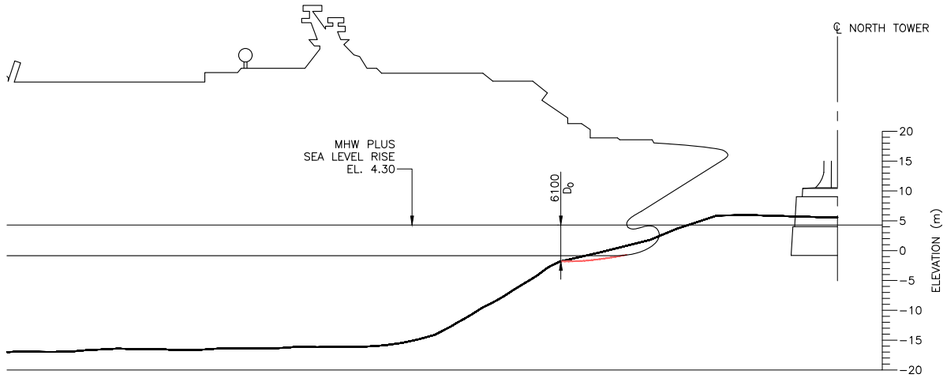
FILE No. | PROJECT No. 83118 | REG. . | DRAWING No. 01481–B205

CANCEL PRINTS BEARING PREVIOUS LETTER

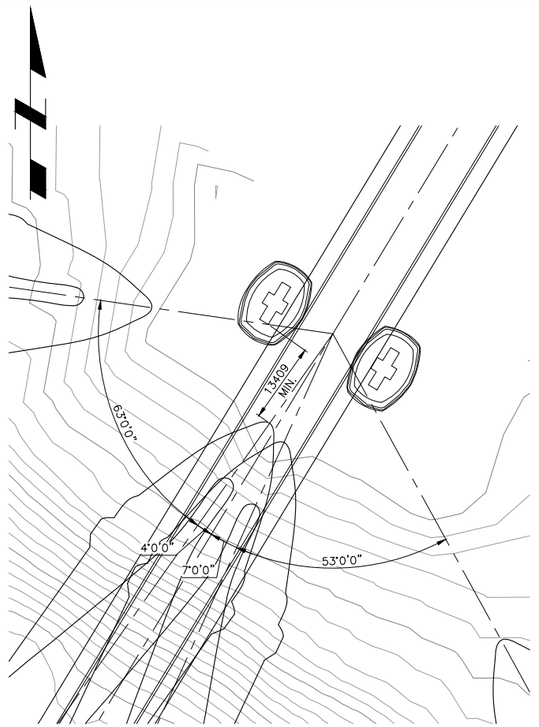
H:\308\1-(07-08)



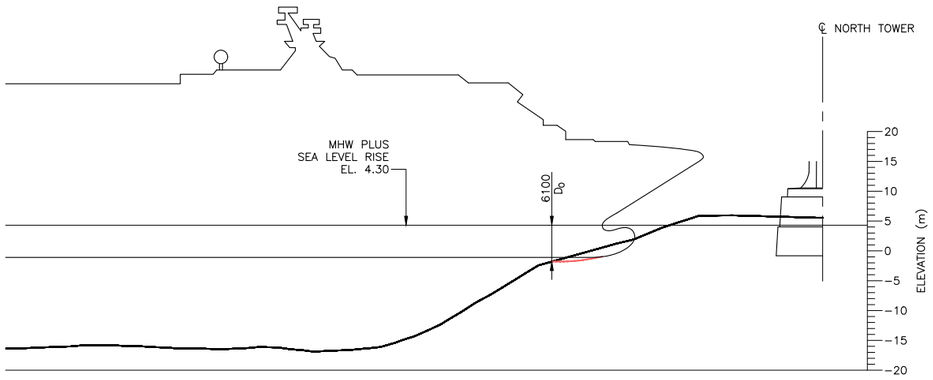

NORTH TOWER ELEVATION AT 63°
(LOADED)
SCALE: 1:500



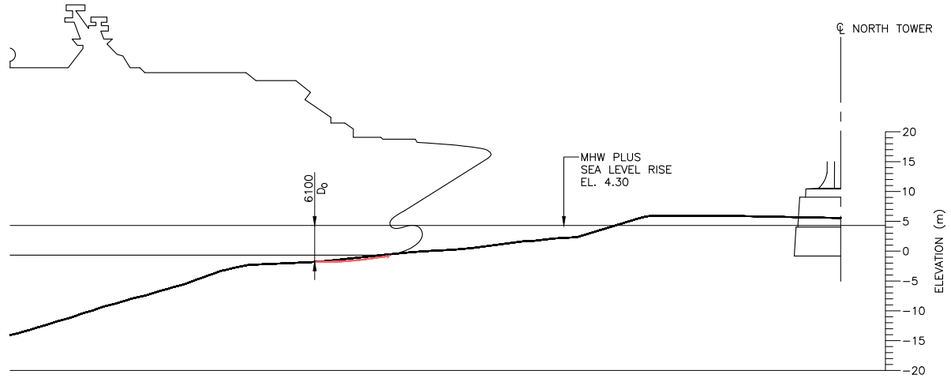

NORTH TOWER ELEVATION AT 4°
(LOADED)
SCALE: 1:500




NORTH TOWER PLAN
SCALE: 1:500




NORTH TOWER ELEVATION AT 7°
(LOADED)
SCALE: 1:500




NORTH TOWER ELEVATION AT 53°
(LOADED)
SCALE: 1:500

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

NOTE:

1. NORTH TOWER PEDESTAL SHOWN PERPENDICULAR FOR REFERENCE PURPOSES ONLY.

VESSEL ID #81 (CRUISE SHIP)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 15,810 tonnes |
| LENGTH OVERALL(LOA): | 186m |
| BREADTH/BEAM: | 25m |
| DRAFT($D_0$): | 6.1m |
| DRAFT($D_{EB}$): | 6.1m |

MMM GROUP

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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
NORTH TOWER
VESSEL SCENARIOS – V81

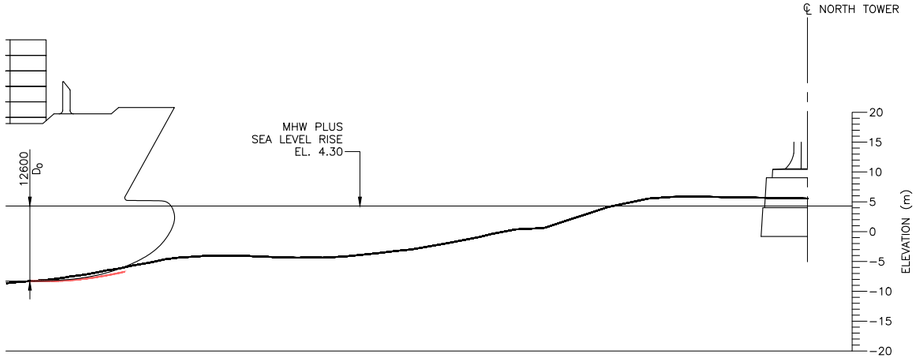
PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

DESIGNED . DATE
CHECKED . DATE
DRAWN SH DATE
SCALE
NEGATIVE No.

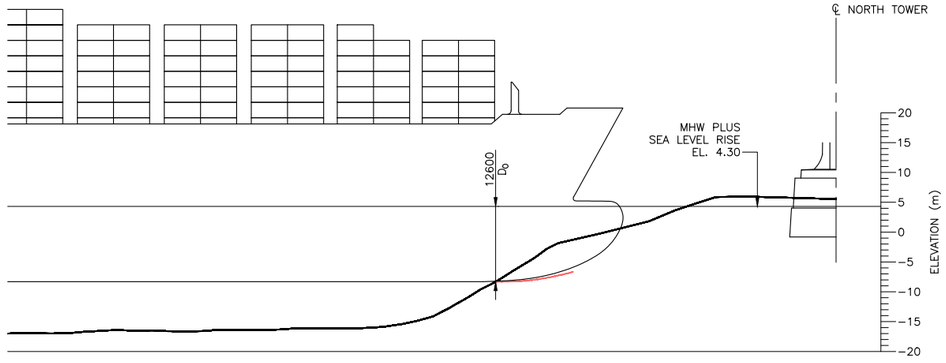
FILE No. | PROJECT No. 83118 | REG. . | DRAWING No. 01481–B206

CANCEL PRINTS BEARING PREVIOUS LETTER

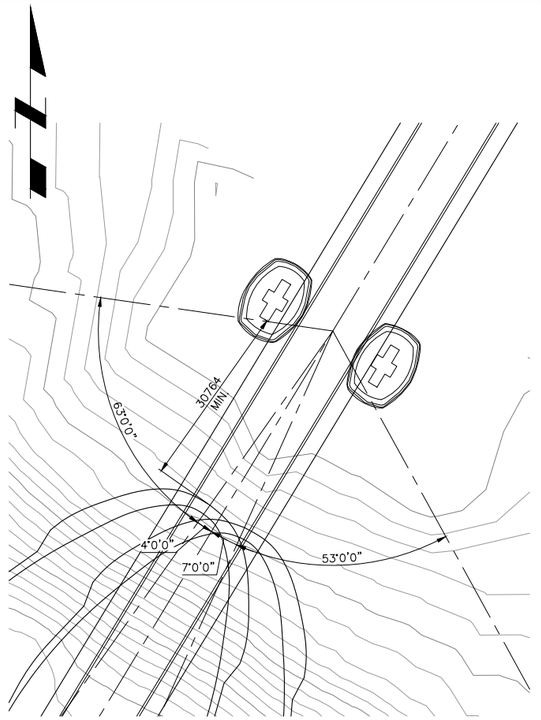
H-308-r1-(07-08)



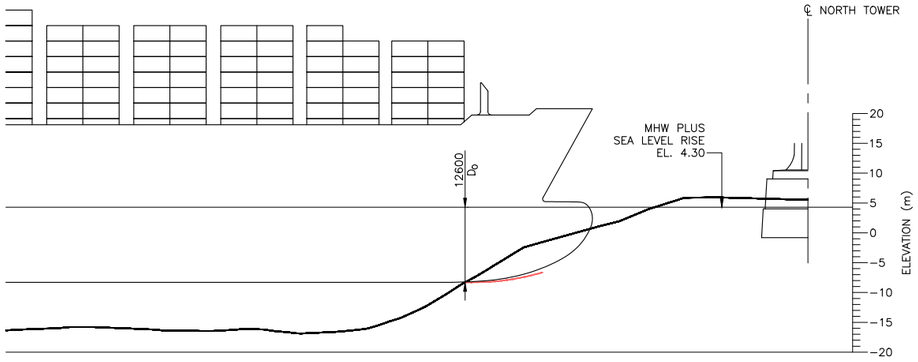

NORTH TOWER ELEVATION AT 63°
(LOADED)
SCALE: 1:500



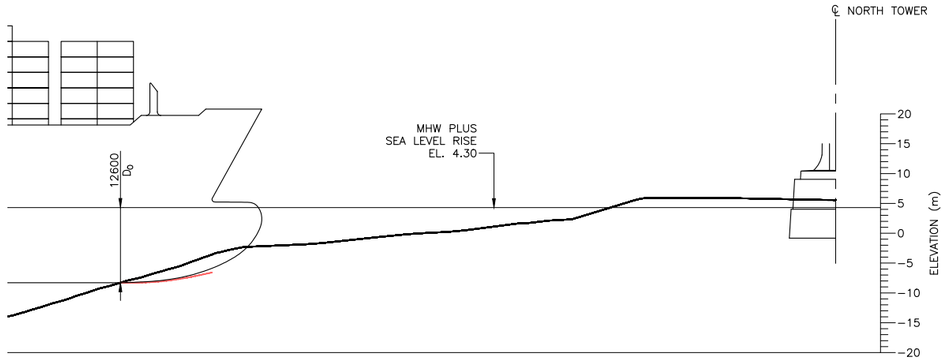

NORTH TOWER ELEVATION AT 4°
(LOADED)
SCALE: 1:500




NORTH TOWER PLAN
SCALE: 1:500




NORTH TOWER ELEVATION AT 7°
(LOADED)
SCALE: 1:500




NORTH TOWER ELEVATION AT 53°
(LOADED)
SCALE: 1:500

VESSEL ID #12 (CONTAINER)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 210,000 tonnes |
| LENGTH OVERALL(LOA): | 300m |
| BREADTH/BEAM: | 50m |
| DRAFT($D_0$): | 12.6m |
| DRAFT($D_{EB}$): | 12.6m |

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

NOTE:

1. NORTH TOWER PEDESTAL SHOWN PERPENDICULAR FOR REFERENCE PURPOSES ONLY.

MMM GROUP

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REVISIONS

BRITISH COLUMBIA | Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
NORTH TOWER
VESSEL SCENARIOS – V12

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

DESIGNED . DATE
CHECKED . DATE
DRAWN SH DATE
SCALE
NEGATIVE No.

FILE No. | PROJECT No. 83118 | REG. . | DRAWING No. 01481–B207

CANCEL PRINTS BEARING PREVIOUS LETTER

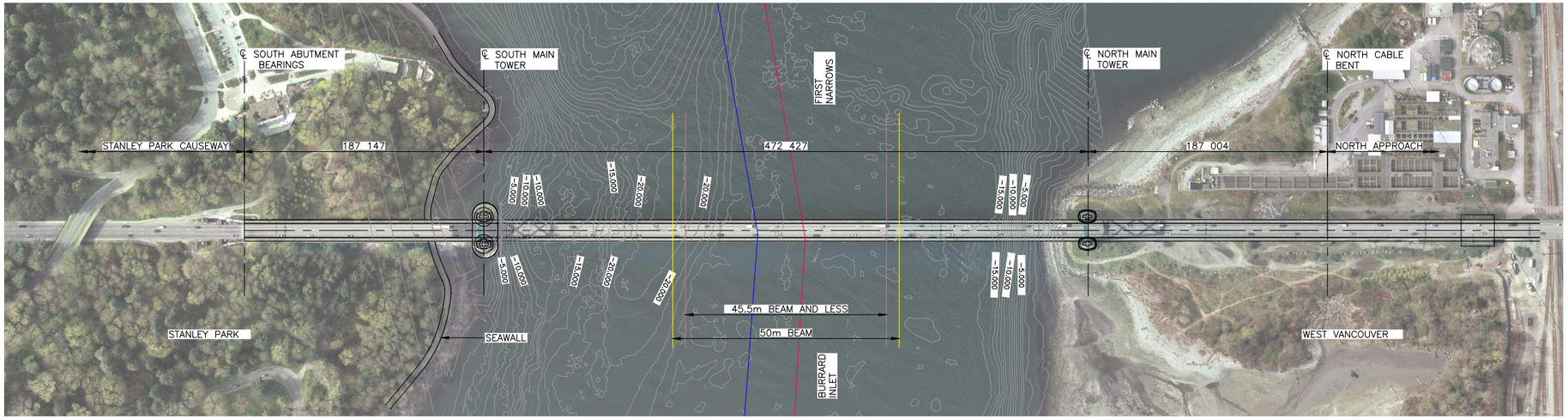
H-308;r1-r(07-08)

# APPENDIX

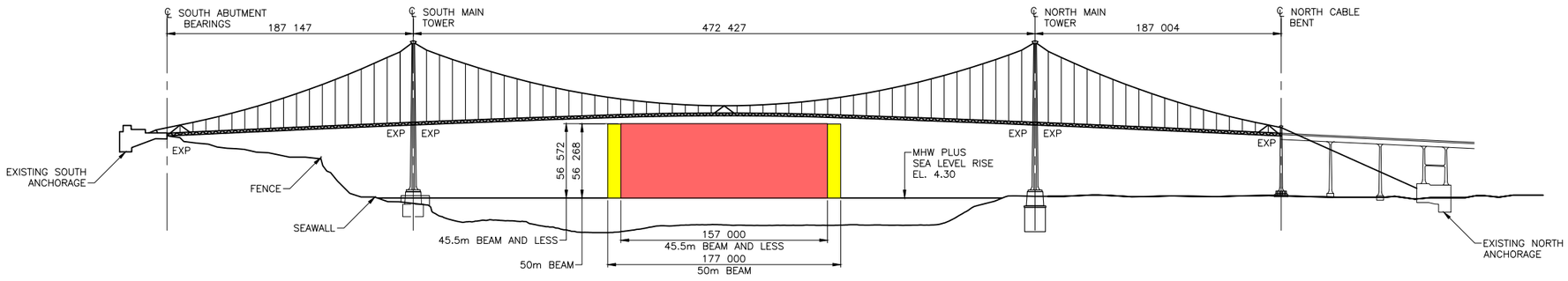
# C

## CONCEPT DRAWINGS FOR PHYSICAL PROTECTION

# APPENDIX




PLAN
SCALE: 1:2000




ELEVATION
SCALE: 1:2000

## NAVIGATION CHANNEL LEGEND

- 45.5m BEAM AND LESS – MAX VESSEL AIR DRAFT = 56.572m HHWLT
- 50m BEAM – MAX VESSEL AIR DRAFT = 56.268m HHWLT

## NOTE:

1. ALL ELEVATIONS ARE IN METERS AND REFERENCED TO CHART DATUM.

MMM GROUP

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REVISIONS

BRITISH COLUMBIA | Ministry of Transportation & Infrastructure
South Coast Region

# 01481 LIONS GATE BRIDGE
# VESSEL COLLISION RISK MITIGATION STUDY
# EXISTING STRUCTURE AND CHANNEL

.

PREPARED UNDER THE DIRECTION OF

KEITH HOLMES
ENGINEER OF RECORD

DATE

DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
SCALE AS SHOWN
NEGATIVE No.

FILE No.

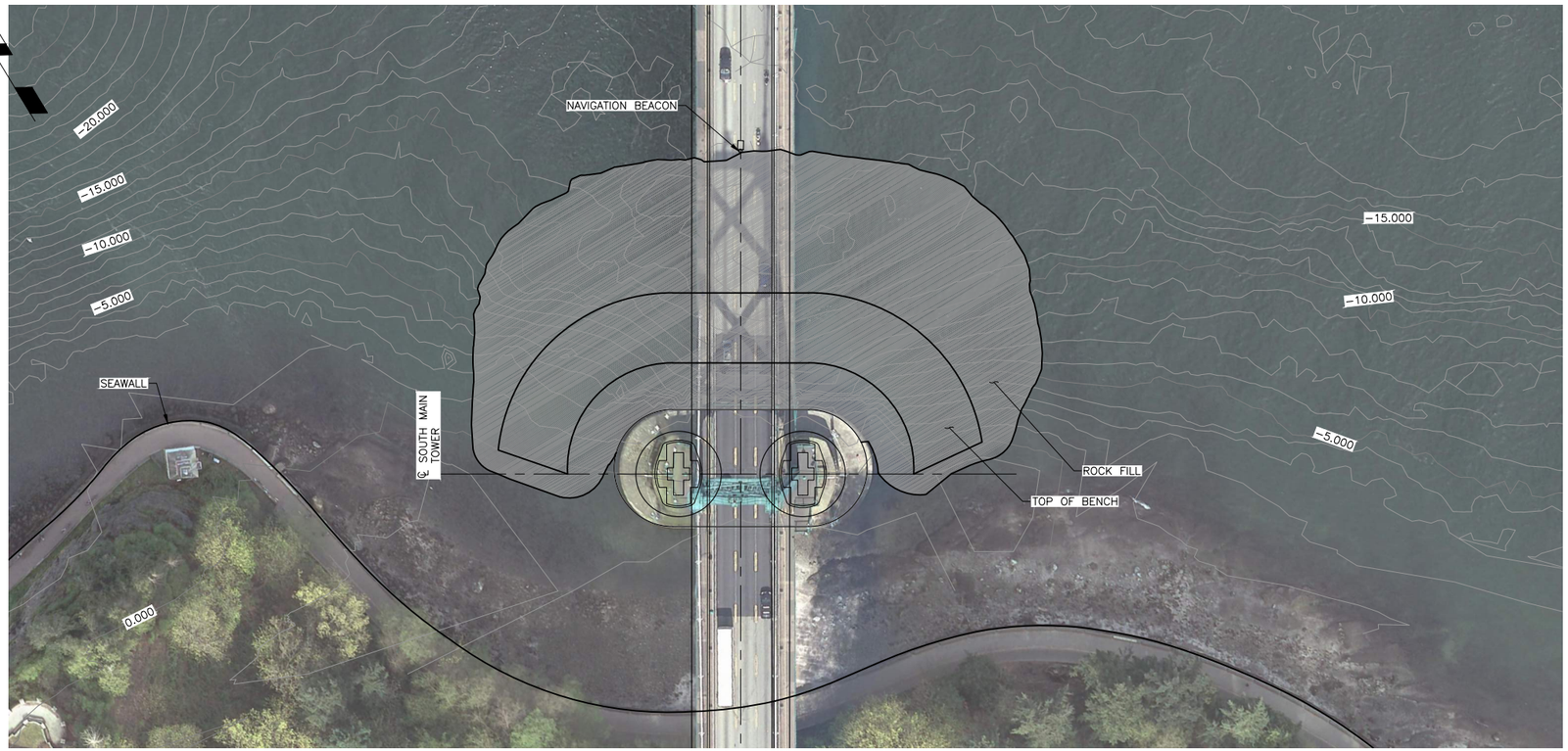
PROJECT No. 83118

REG. .

DRAWING No. 01481–C001

CANCEL PRINTS BEARING PREVIOUS LETTER

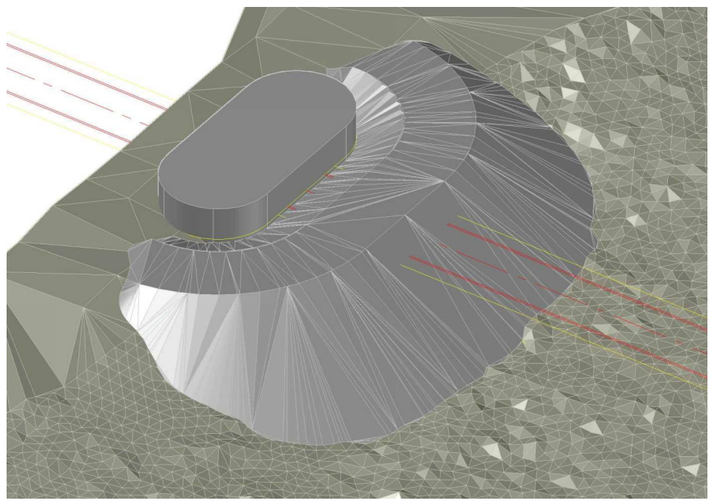
H-308;1=1-(07-98)



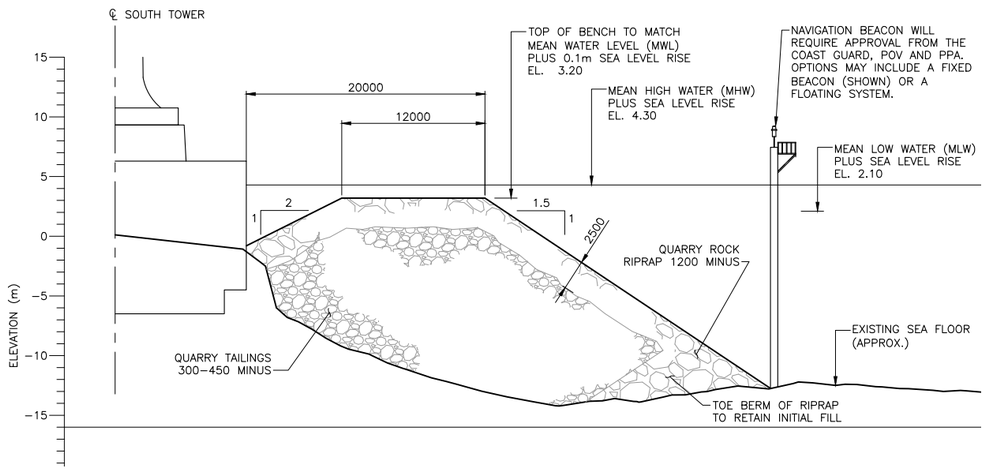

PLAN
SCALE: 1:500

SOUTH TOWER, LOOKING NORTH-WEST
PHOTO TAKEN ON MAY 7, 2015 AT 8:30AM
OBSERVED TIDE ELEVATION = 3.42m

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION



3D VIEW, LOOKING SOUTH-WEST
SCALE: 1:500




TYPICAL CROSS-SECTION
(PARALLEL AND ON BRIDGE CENTERLINE)
SCALE: 1:250

NOTE:

1. ALL ELEVATIONS ARE IN METERS AND REFERENCED TO CHART DATUM.

MMM GROUP

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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
# ROCK FILL PROTECTION BERM CONCEPT

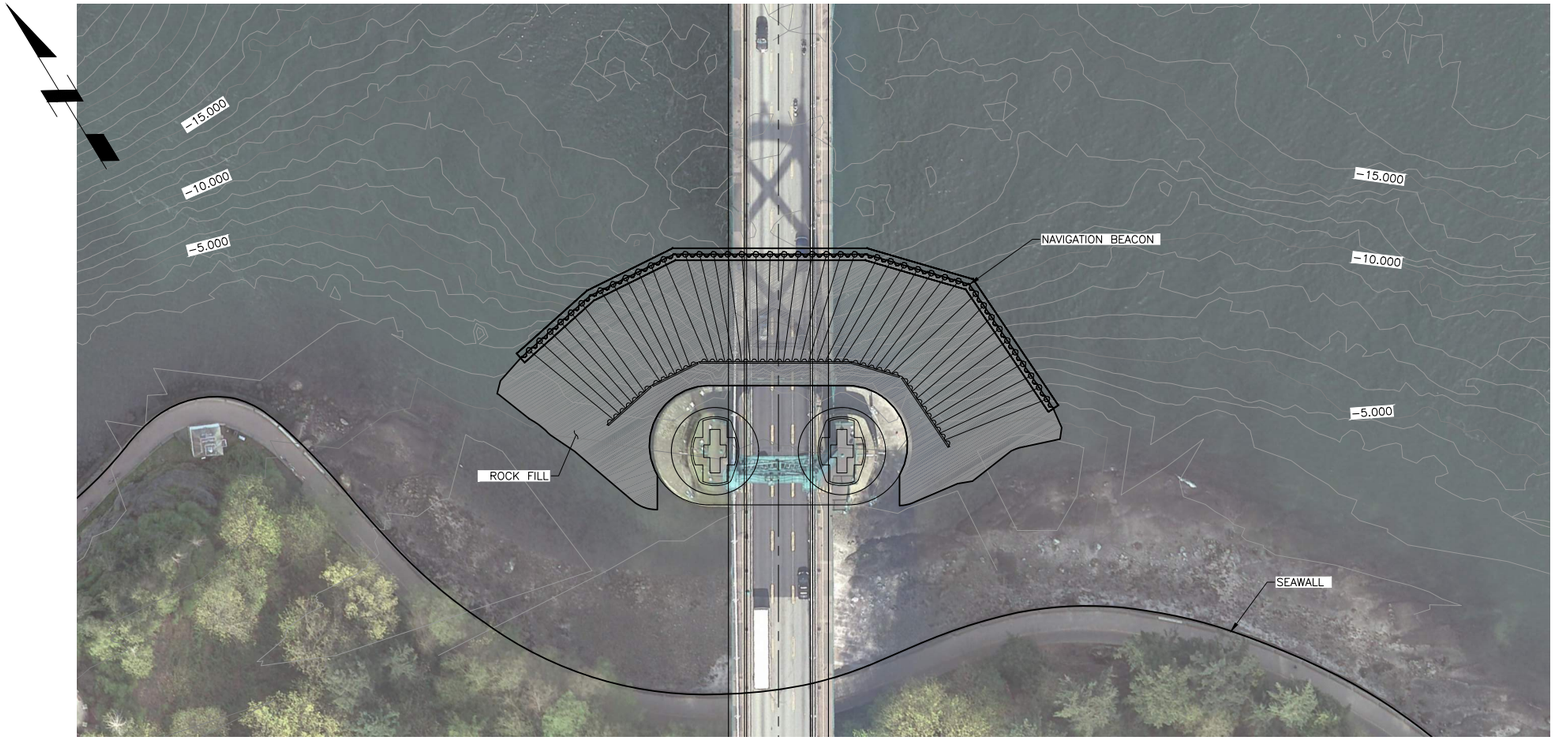
PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
SCALE AS SHOWN
NEGATIVE No.

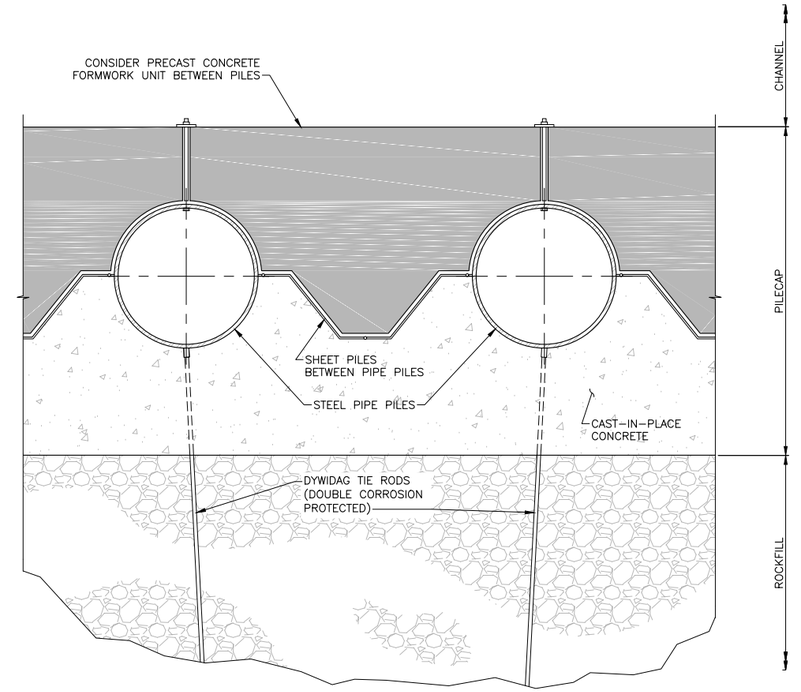
FILE No. | PROJECT No. 83118 | REG. . | DRAWING No. 01481-C002

CANCEL PRINTS BEARING PREVIOUS LETTER

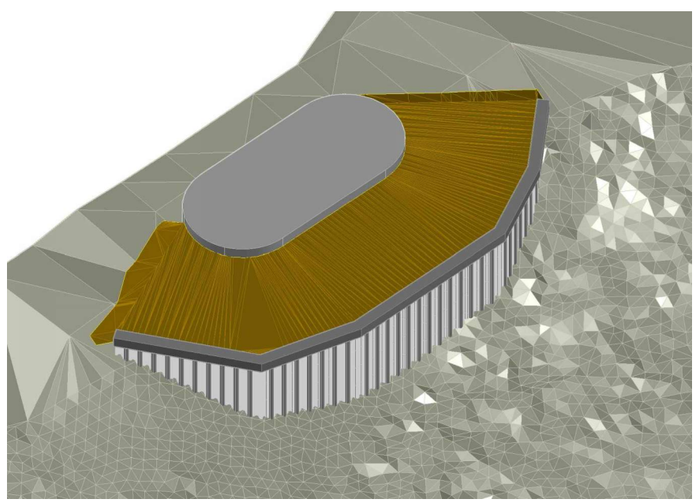
H-3638-11-4(07-08)



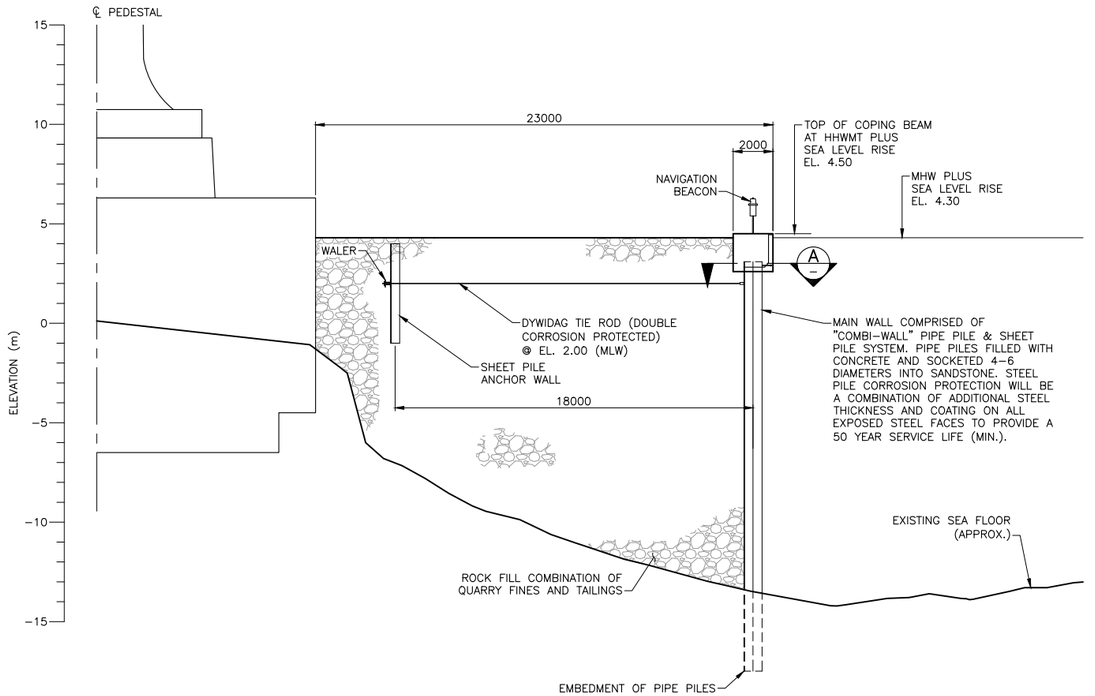

PLAN
SCALE: 1:500




SECTION A "COMBI-WALL" PLAN DETAIL
SCALE 1:20



3D VIEW, LOOKING SOUTH-WEST
SCALE: 1:500




TYPICAL CROSS-SECTION
SCALE: 1:150

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

NOTES:

1. ALL ELEVATIONS ARE IN METERS AND REFERENCED TO CHART DATUM.
2. TIE ROD INSTALLATION TO BE COORDINATED WITHIN THE TIDAL REGIME.
3. TIE ROD CONNECTION TO TOWER FOUNDATION POSSIBLE FOR TEMPORARY SUPPORT.

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REVISIONS

BRITISH COLUMBIA | Ministry of Transportation & Infrastructure
South Coast Region

# 01481 LIONS GATE BRIDGE
## VESSEL COLLISION RISK MITIGATION STUDY
## "COMBI-WALL" PROTECTION CONCEPT

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
SCALE AS SHOWN
NEGATIVE No.

| FILE No. | PROJECT No. | REG. | DRAWING No. |
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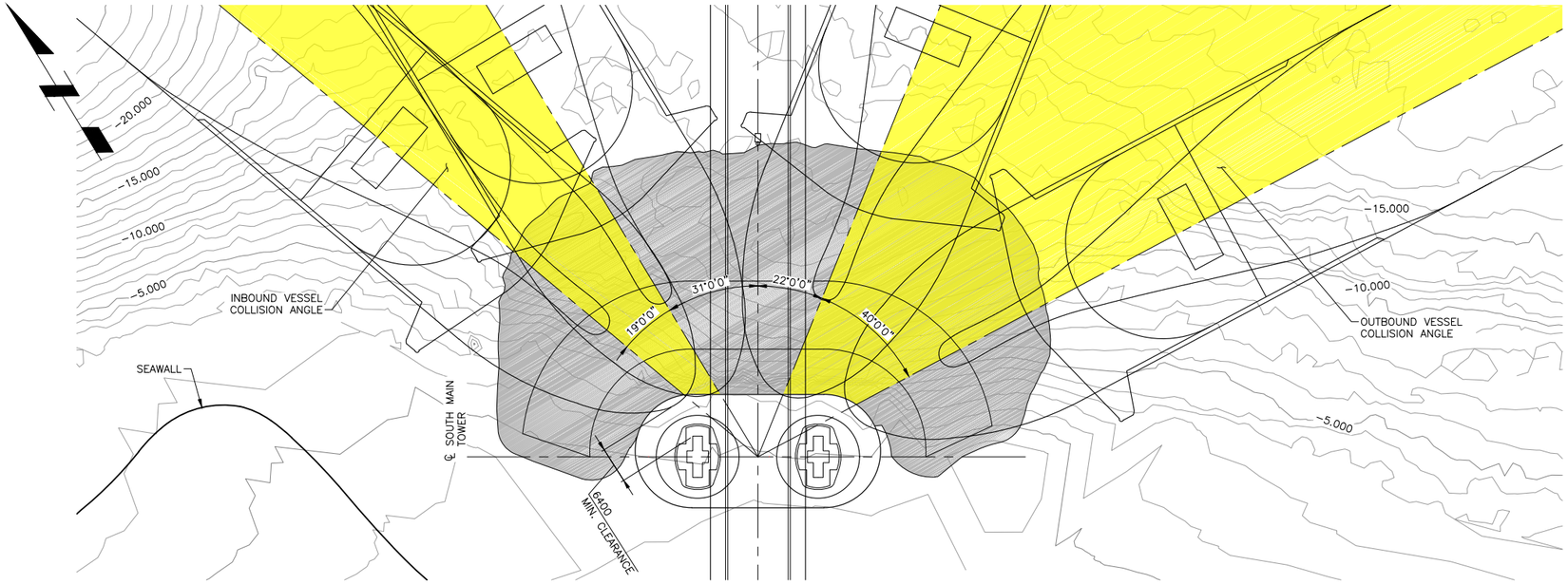
| | 83118 | . | 01481-C003 |

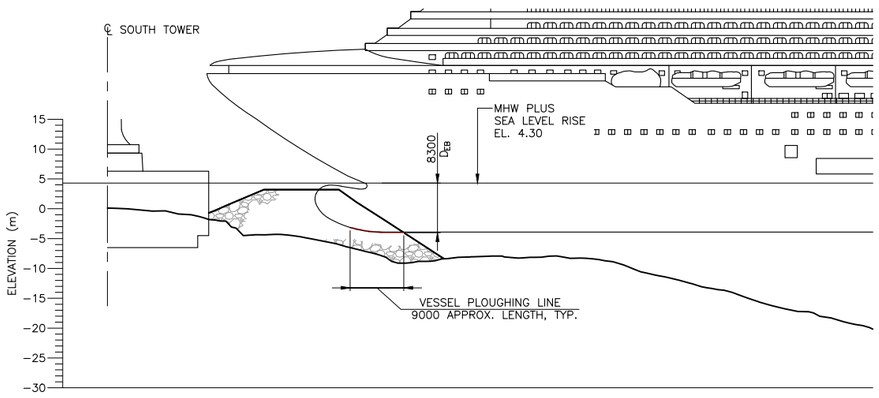
CANCEL PRINTS BEARING PREVIOUS LETTER

H-308-r1-(07-08)

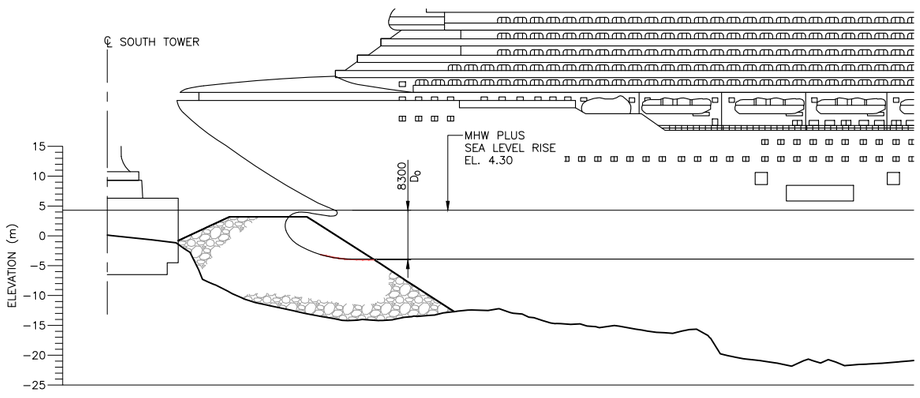
PRELIMINARY
NOT ISSUED FOR CONSTRUCTION



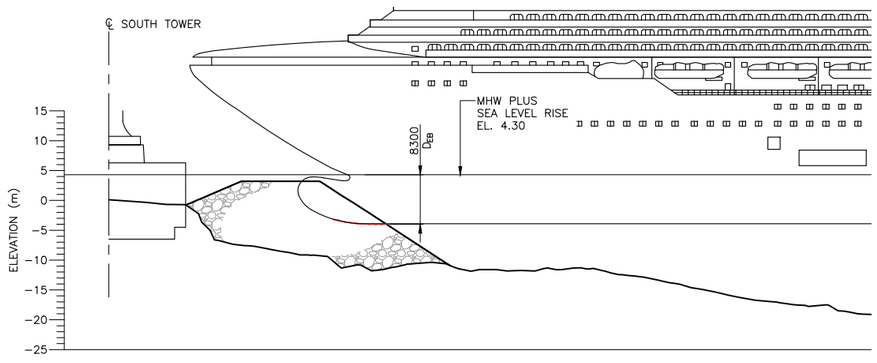

PLAN
SCALE: 1:500



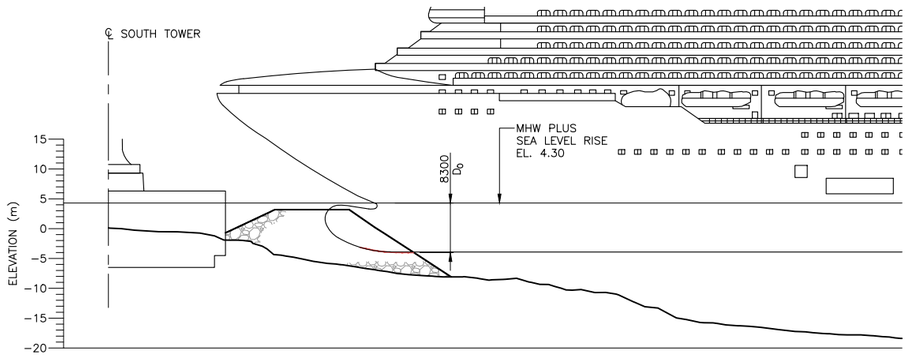

SOUTH TOWER ELEVATION AT 19°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 22°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 31°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 40°
(LOADED)
SCALE: 1:500

VESSEL ID #75 (CRUISE SHIP)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 61,410 tonnes |
| LENGTH OVERALL(LOA): | 317m |
| BREADTH/BEAM: | 37m |
| DRAFT($D_0$): | 8.3m |
| DRAFT($D_{EB}$): | 8.3m |

MMM GROUP

| Rev | Date | Description | Init |
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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
PROTECTION BERM CONCEPT
V75 VESSEL COLLISION SCENARIO

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

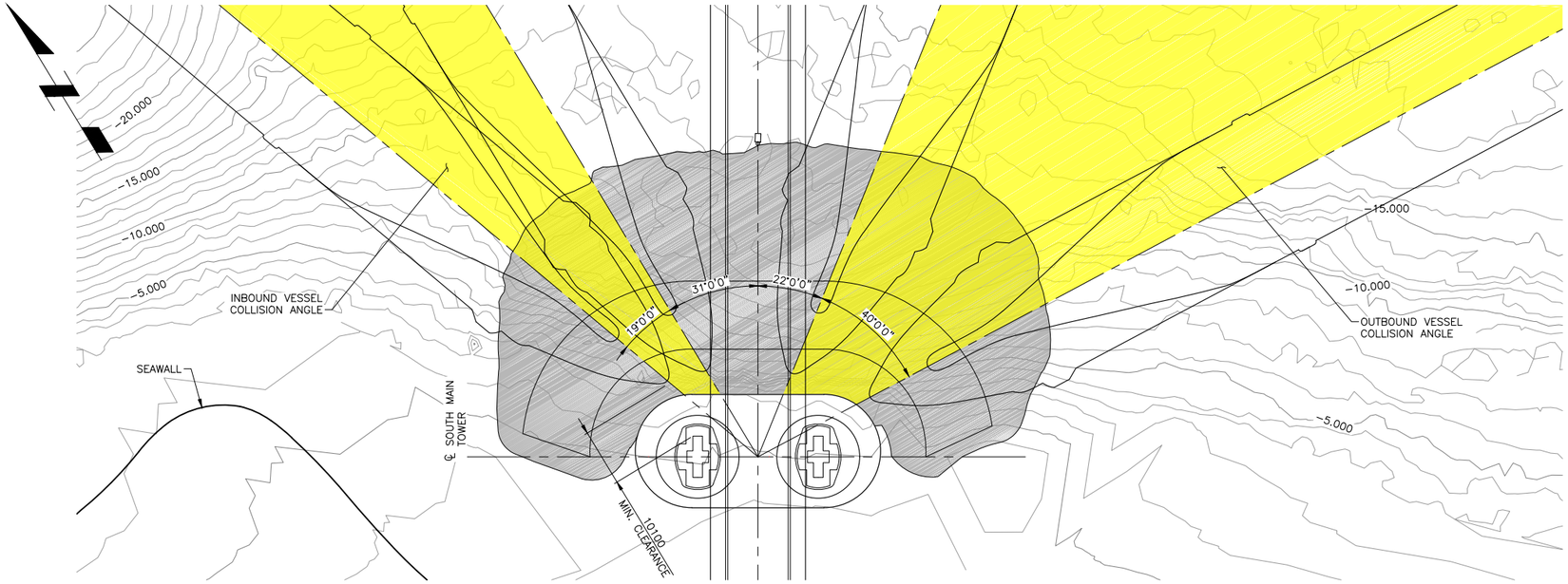
DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
SCALE AS SHOWN
NEGATIVE No.

| FILE No. | PROJECT No. | REG. | DRAWING No. |
|---|---|---|---|
| | 83118 | . | 01481-C004 |

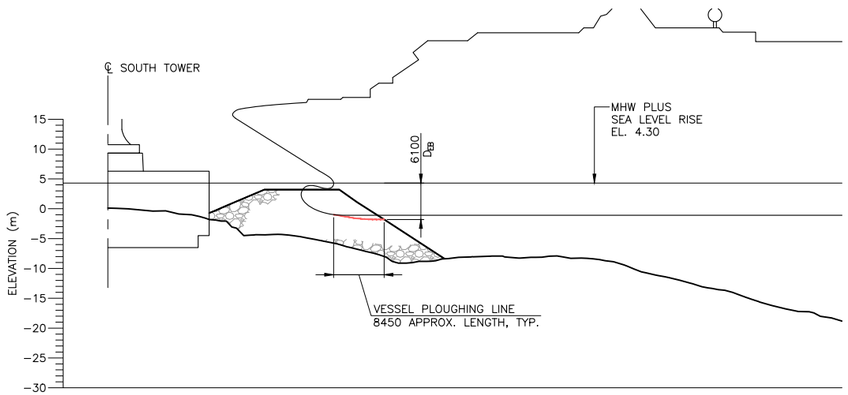
CANCEL PRINTS BEARING PREVIOUS LETTER

H-308;r1-(07-08)

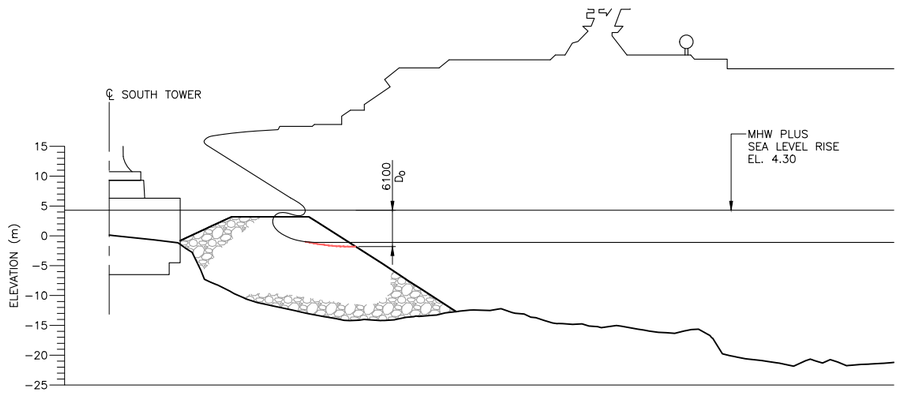
PRELIMINARY
NOT ISSUED FOR CONSTRUCTION



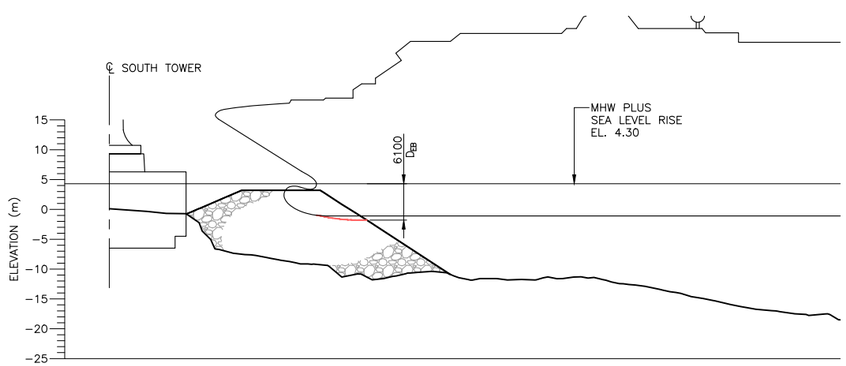

PLAN
SCALE: 1:500




SOUTH TOWER ELEVATION AT 19°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 22°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 31°
(LOADED)
SCALE: 1:500

SOUTH TOWER ELEVATION AT 40°
(LOADED)
SCALE: 1:500

VESSEL ID #81 (CRUISE SHIP)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 15,810 tonnes |
| LENGTH OVERALL(LOA): | 186m |
| BREADTH/BEAM: | 25m |
| DRAFT($D_D$): | 6.1m |
| DRAFT($D_{EB}$): | 6.1m |

MMM GROUP

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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
PROTECTION BERM CONCEPT
V81 VESSEL COLLISION SCENARIO

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

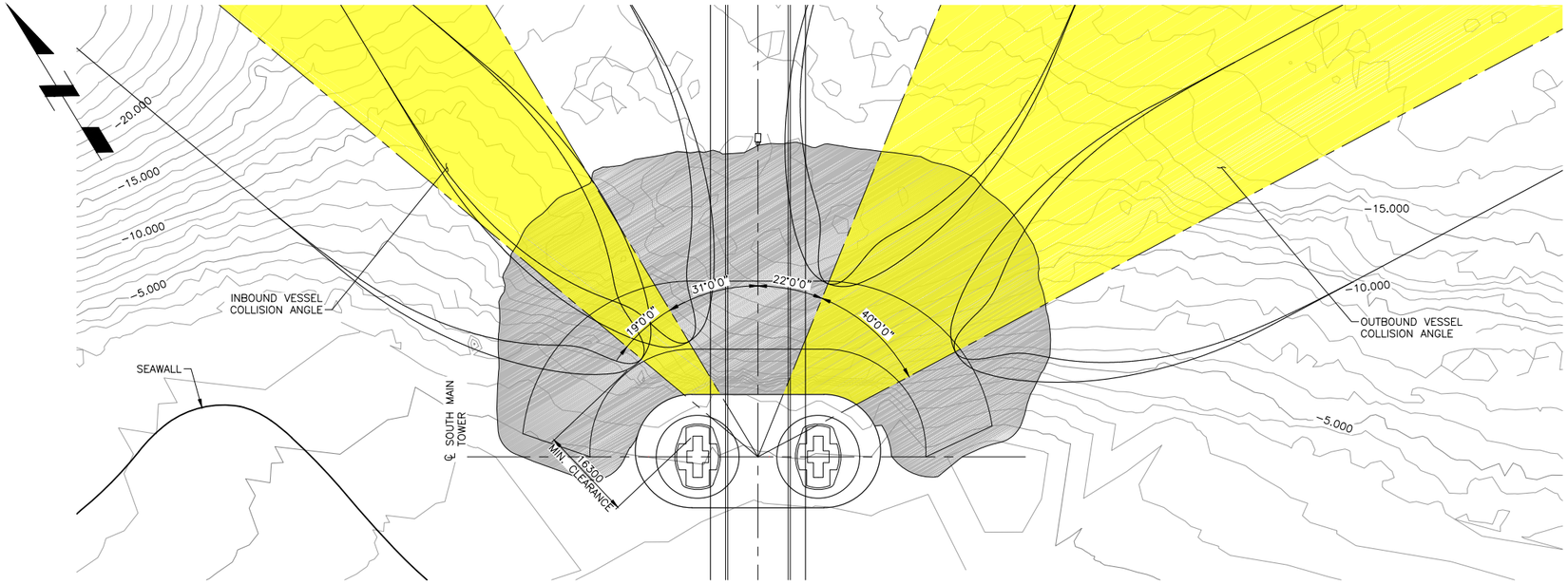
DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
SCALE AS SHOWN
NEGATIVE No.

| FILE No. | PROJECT No. | REG. | DRAWING No. |
|---|---|---|---|
| | 83118 | . | 01481-C005 |

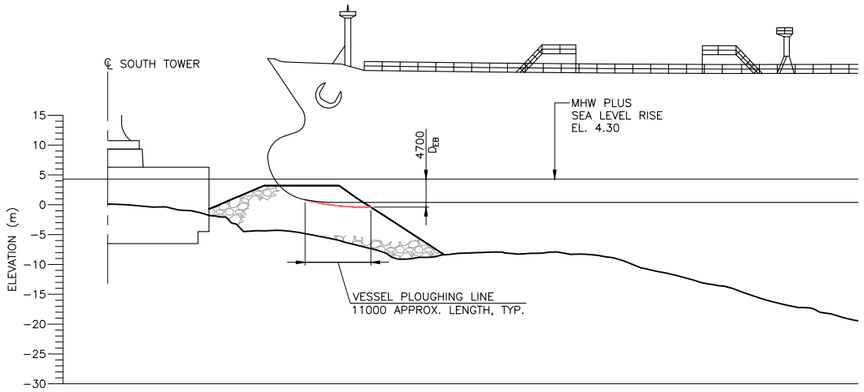
CANCEL PRINTS BEARING PREVIOUS LETTER

H-308-41-1(07-08)

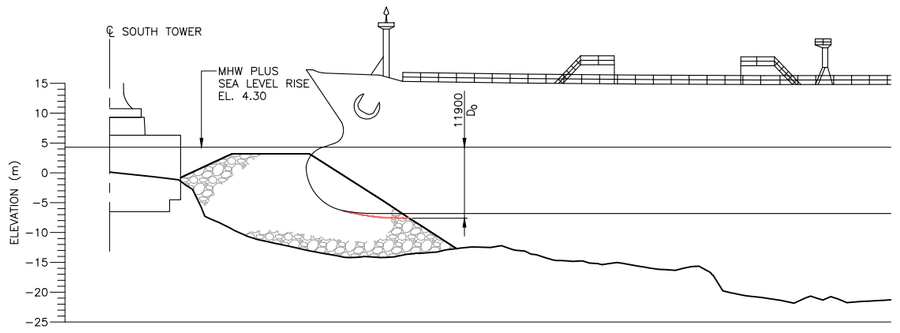
PRELIMINARY
NOT ISSUED FOR CONSTRUCTION



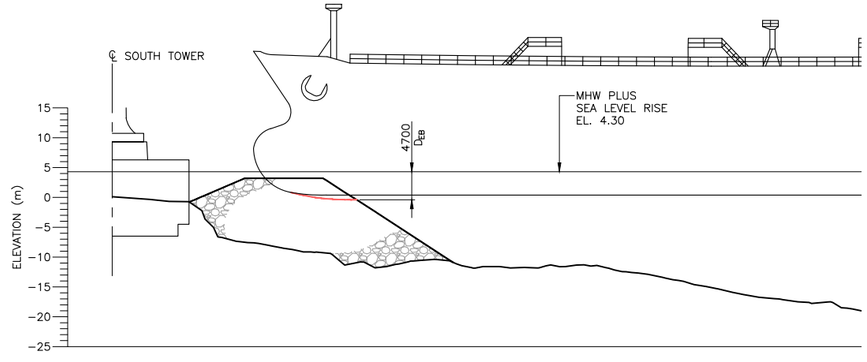

PLAN
SCALE: 1:500



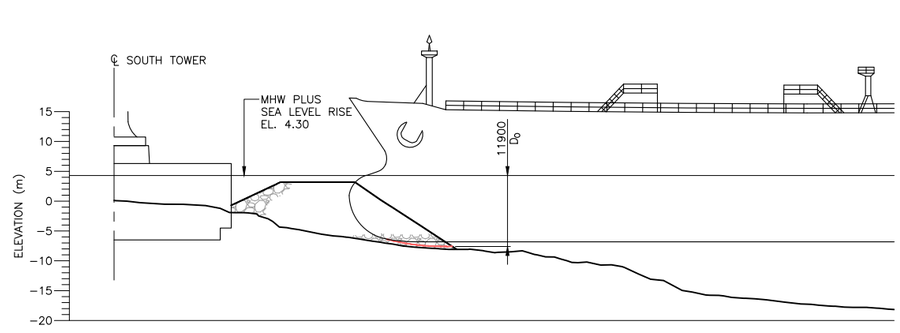

SOUTH TOWER ELEVATION AT 19°
(BALLASTED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 22°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 31°
(BALLASTED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 40°
(LOADED)
SCALE: 1:500

## VESSEL ID #10 (TANKER)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 120,000 tonnes |
| LENGTH OVERALL(LOA): | 250m |
| BREADTH/BEAM: | 44m |
| DRAFT($D_0$): | 11.9m |
| DRAFT($D_{EB}$): | 4.7m |

MMM GROUP

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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
PROTECTION BERM CONCEPT
V10 VESSEL COLLISION SCENARIO

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

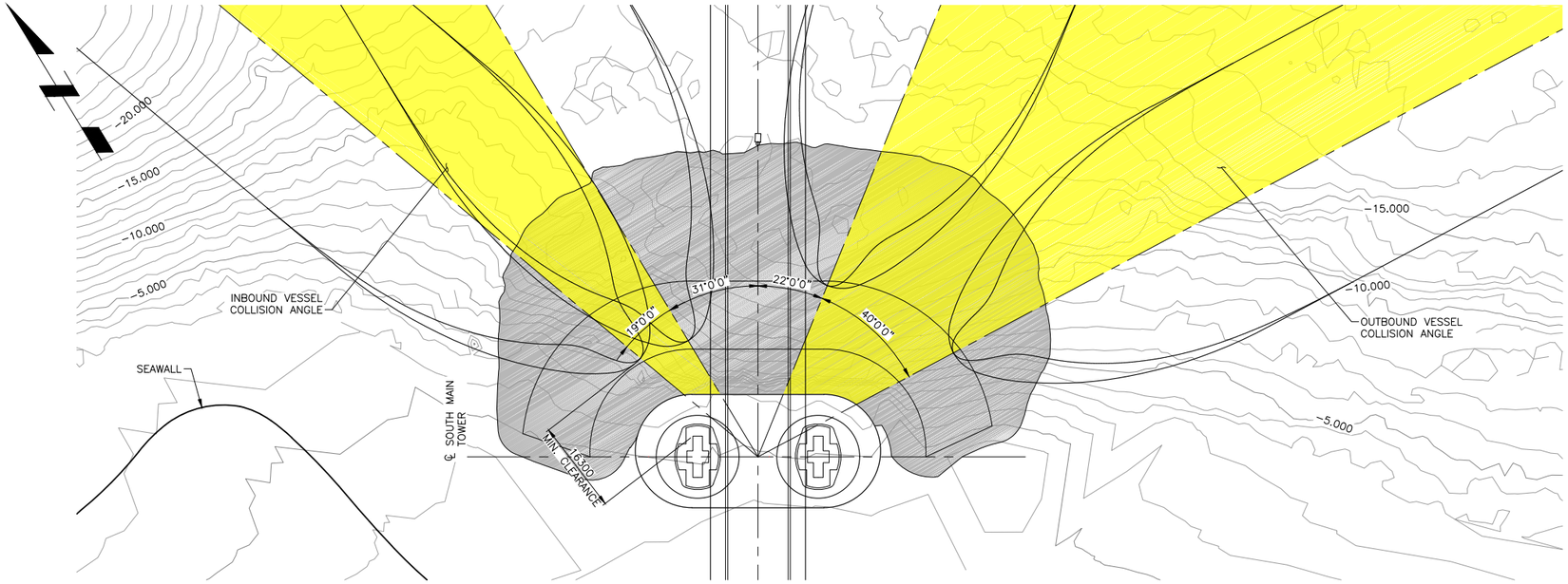
DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
SCALE AS SHOWN
NEGATIVE No.

FILE No.
PROJECT No. 83118
REG. .
DRAWING No. 01481-C006

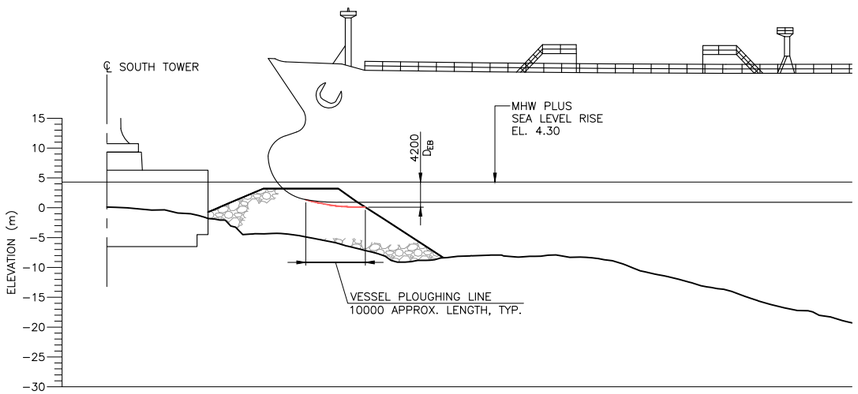
CANCEL PRINTS BEARING PREVIOUS LETTER

H-308;1-1=(07-08)

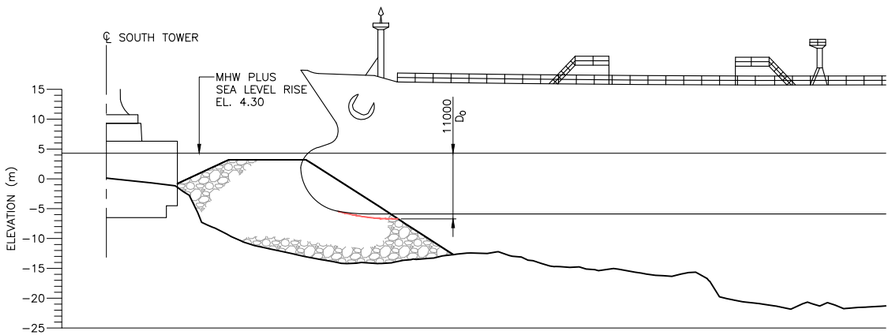
PRELIMINARY
NOT ISSUED FOR CONSTRUCTION



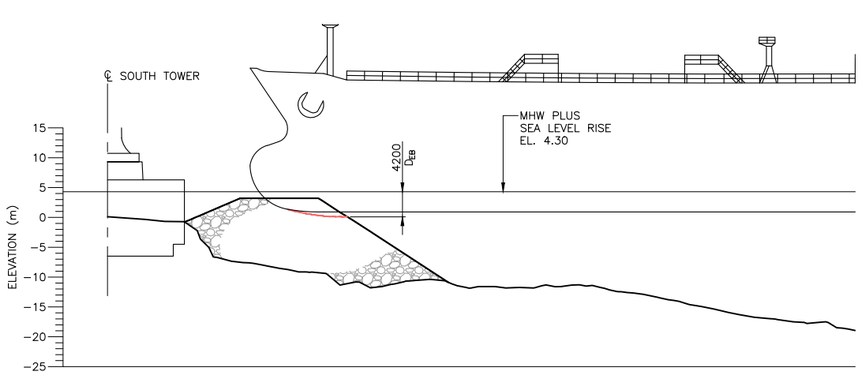

PLAN
SCALE: 1:500



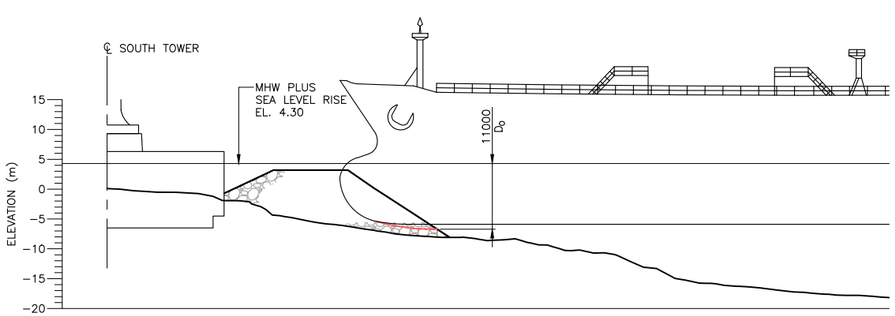

SOUTH TOWER ELEVATION AT 19°
(BALLASTED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 22°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 31°
(BALLASTED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 40°
(LOADED)
SCALE: 1:500

## VESSEL ID #34 (TANKER)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 70,000 tonnes |
| LENGTH OVERALL(LOA): | 228m |
| BREADTH/BEAM: | 32m |
| DRAFT($D_O$): | 11.0m |
| DRAFT($D_{EB}$): | 4.2m |

MMM GROUP

| Rev | Date | Description | Init |
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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
# PROTECTION BERM CONCEPT
# V34 VESSEL COLLISION SCENARIO

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
SCALE AS SHOWN
NEGATIVE No.

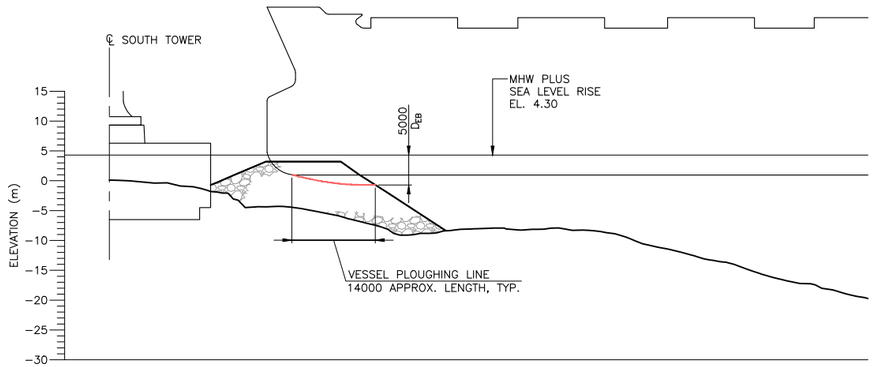
| FILE No. | PROJECT No. | REG. | DRAWING No. |
|---|---|---|---|
| | 83118 | . | 01481-C007 |

CANCEL PRINTS BEARING PREVIOUS LETTER

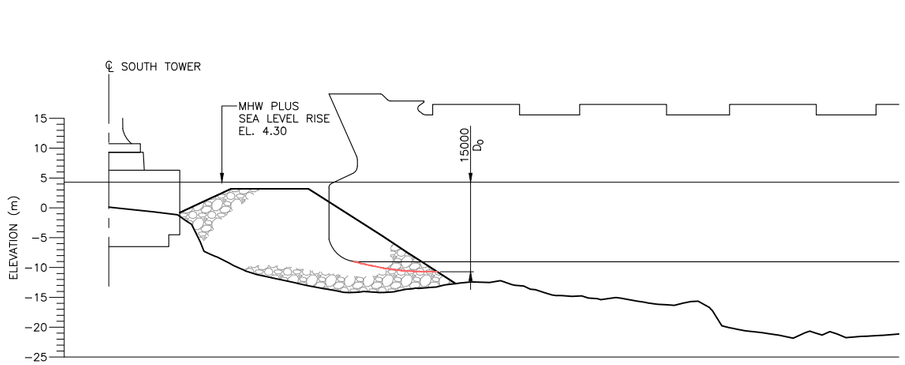
H-3638-11-C(07-08)

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

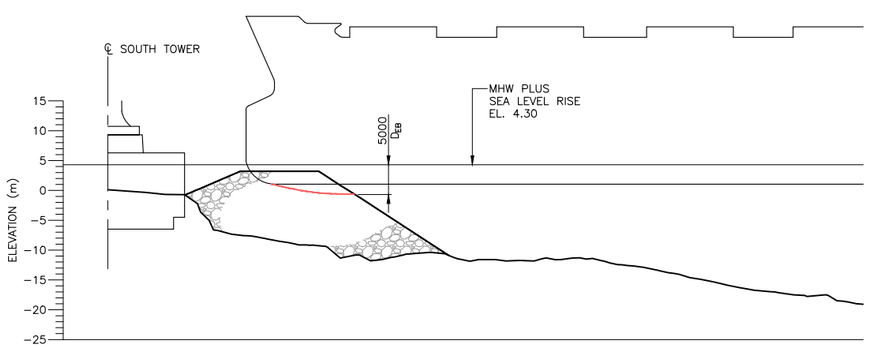
PLAN
SCALE: 1:500



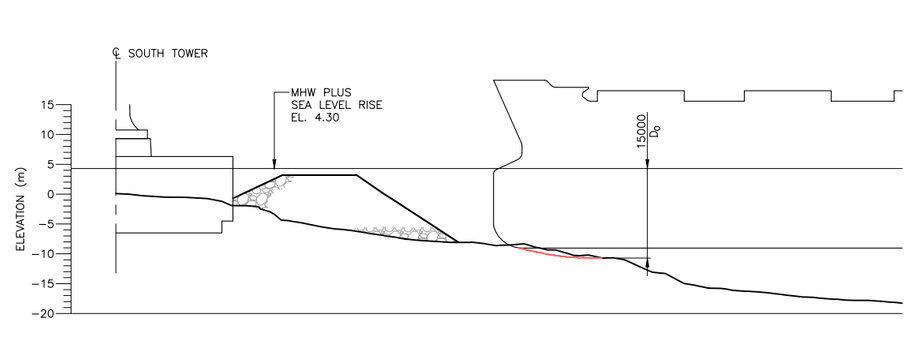

SOUTH TOWER ELEVATION AT 19°
(BALLASTED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 22°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 31°
(BALLASTED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 40°
(LOADED)
SCALE: 1:500

VESSEL ID #01 (BULKER)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 210,000 tonnes |
| LENGTH OVERALL(LOA): | 300m |
| BREADTH/BEAM: | 50m |
| DRAFT($D_O$): | 15.0m |
| DRAFT($D_{EB}$): | 5.0m |

MMM GROUP

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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
PROTECTION BERM CONCEPT
V01 VESSEL COLLISION SCENARIO

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
SCALE AS SHOWN
NEGATIVE No.

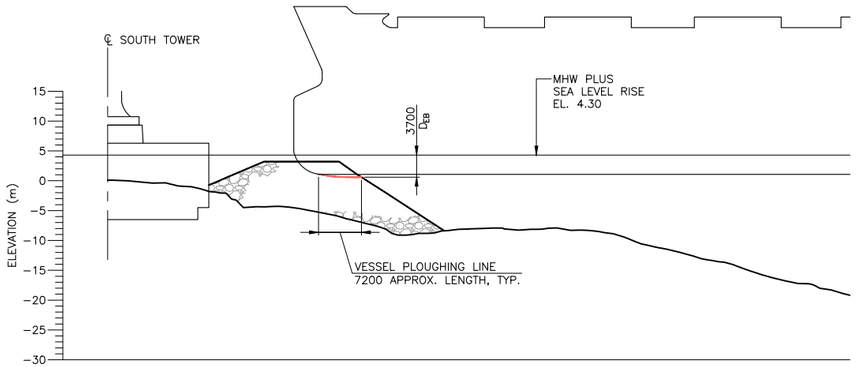
FILE No.
PROJECT No. 83118
REG. .
DRAWING No. 01481-C008

CANCEL PRINTS BEARING PREVIOUS LETTER

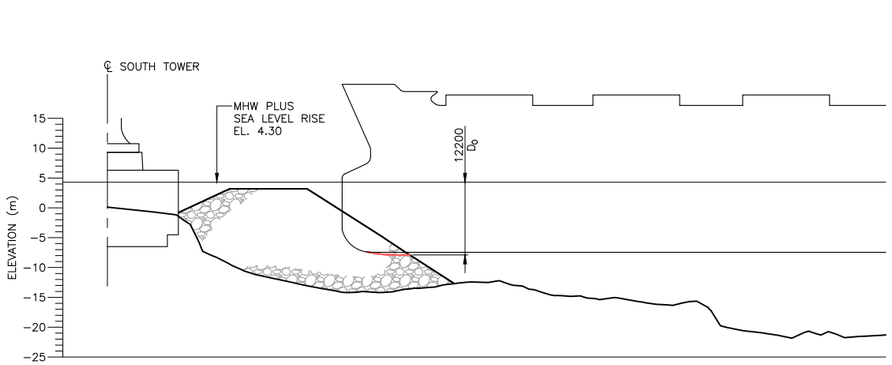
11-308-11-(07-08)

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

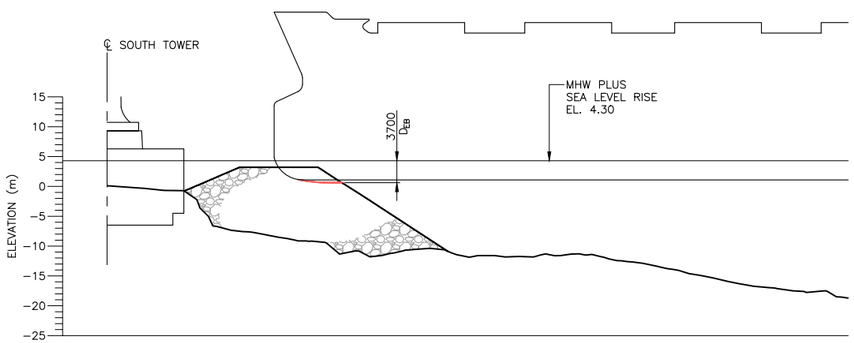
PLAN
SCALE: 1:500




SOUTH TOWER ELEVATION AT 19°
(BALLASTED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 22°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 31°
(BALLASTED)
SCALE: 1:500

SOUTH TOWER ELEVATION AT 40°
(LOADED)
SCALE: 1:500

## VESSEL ID #35 (BULKER)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 70,000 tonnes |
| LENGTH OVERALL(LOA): | 199m |
| BREADTH/BEAM: | 36m |
| DRAFT($D_O$): | 12.2m |
| DRAFT($D_{EB}$): | 3.7m |

MMM GROUP

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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
PROTECTION BERM CONCEPT
V35 VESSEL COLLISION SCENARIO

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
SCALE AS SHOWN
NEGATIVE No.

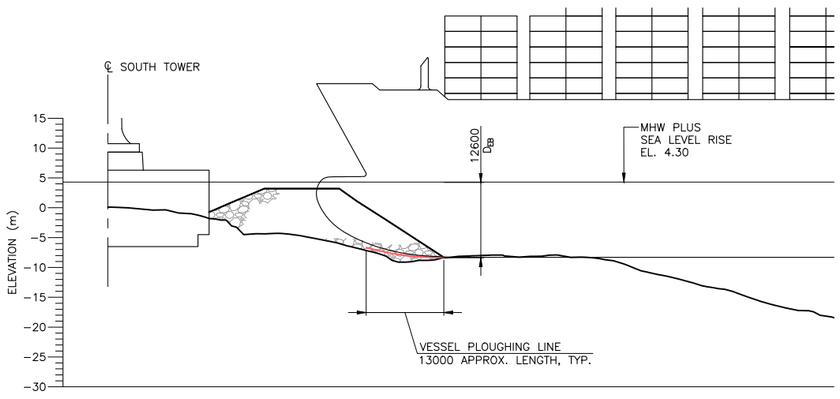
FILE No.
PROJECT No. 83118
REG. .
DRAWING No. 01481-C009

11-308-11-C(07-08)

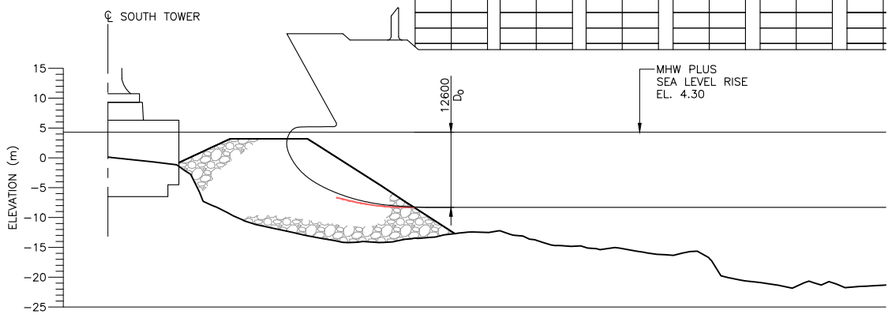
CANCEL PRINTS BEARING PREVIOUS LETTER

PRELIMINARY
NOT ISSUED FOR CONSTRUCTION

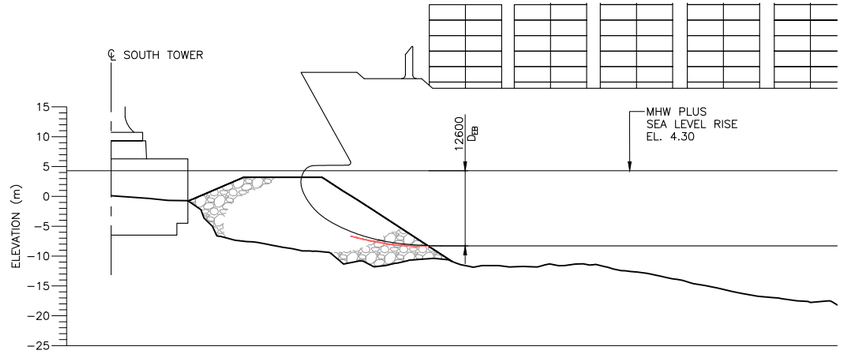
PLAN
SCALE: 1:500



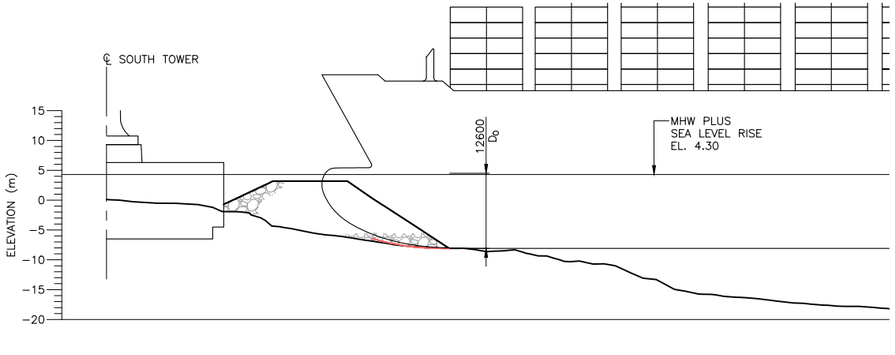

SOUTH TOWER ELEVATION AT 19°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 22°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 31°
(LOADED)
SCALE: 1:500




SOUTH TOWER ELEVATION AT 40°
(LOADED)
SCALE: 1:500

## VESSEL ID #12 (CONTAINER)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 210,000 tonnes |
| LENGTH OVERALL(LOA): | 300m |
| BREADTH/BEAM: | 50m |
| DRAFT($D_D$): | 12.6m |
| DRAFT($D_{EB}$): | 12.6m |

MMM GROUP

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REVISIONS

BRITISH COLUMBIA | Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
PROTECTION BERM CONCEPT
V12 VESSEL COLLISION SCENARIO

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

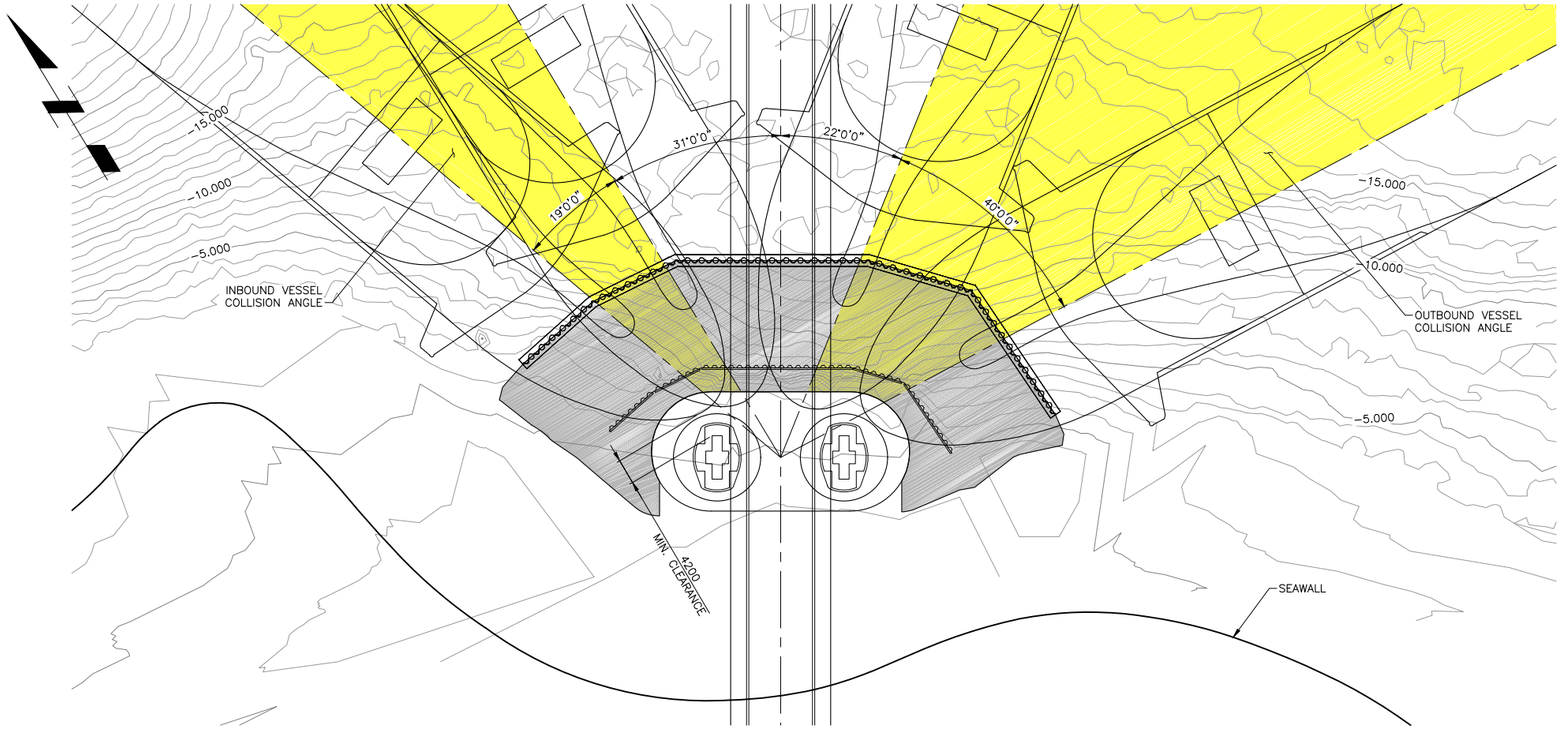
DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
SCALE AS SHOWN
NEGATIVE No.

| FILE No. | PROJECT No. | REG. | DRAWING No. |
|---|---|---|---|
| | 83118 | . | 01481-C010 |

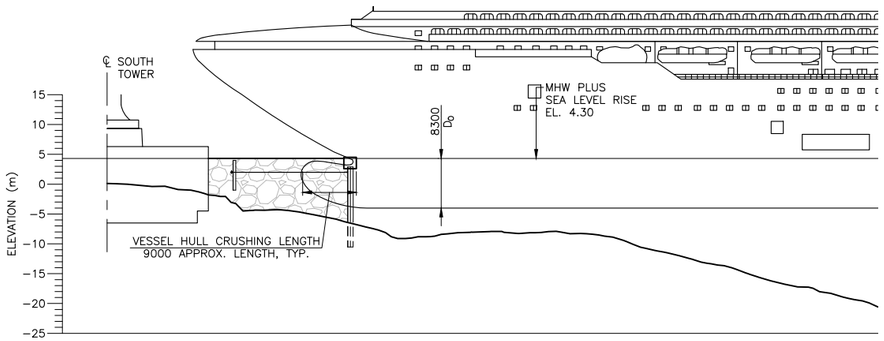
CANCEL PRINTS BEARING PREVIOUS LETTER

H:\568-11-C(07-08)

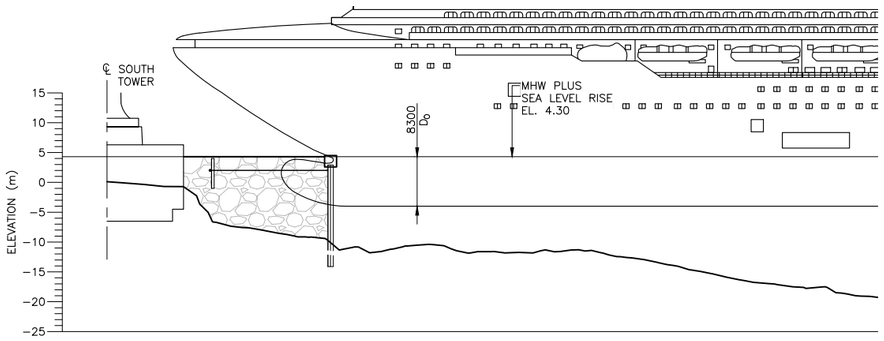
PRELIMINARY
NOT ISSUED FOR CONSTRUCTION



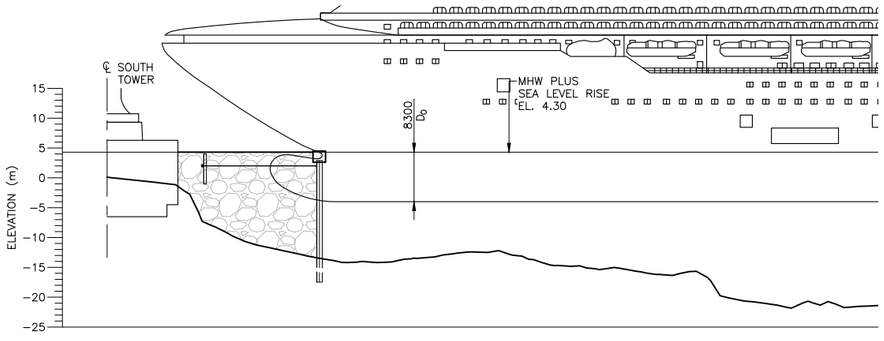

PLAN
SCALE: 1:500
DYWIDAG TIE RODS NOT SHOWN FOR CLARITY



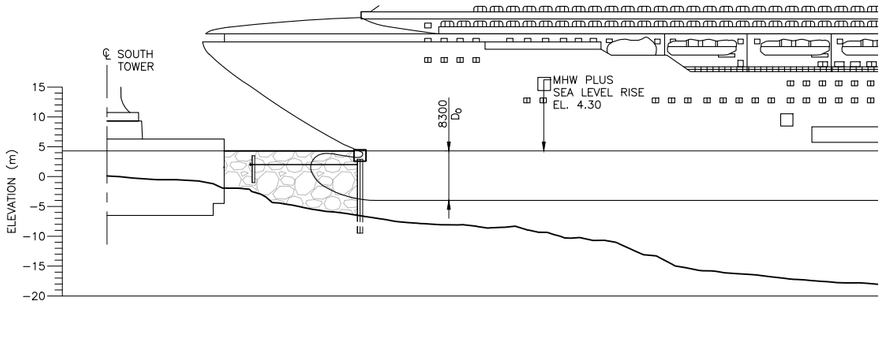

SOUTH TOWER ELEVATION AT 19°
SCALE: 1:500




SOUTH TOWER ELEVATION AT 31°
SCALE: 1:500




SOUTH TOWER ELEVATION AT 22°
SCALE: 1:500




SOUTH TOWER ELEVATION AT 40°
SCALE: 1:500

## VESSEL ID #75 (CRUISE SHIP)

| | |
|---|---|
| VESSEL CAPACITY (DEAD WEIGHT TONNAGE): | 61,410 tonnes |
| LENGTH OVERALL(LOA): | 317m |
| BREADTH/BEAM: | 37m |
| DRAFT($D_O$): | 8.3m |
| DRAFT($D_{EB}$): | 8.3m |

## NOTES:

1. ALL ELEVATIONS ARE IN METERS AND REFERENCED TO CHART DATUM.

MMM GROUP

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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

01481 LIONS GATE BRIDGE
VESSEL COLLISION RISK MITIGATION STUDY
"COMBI-WALL" PROTECTION CONCEPT
V75 VESSEL COLLISION SCENARIO

PREPARED UNDER THE DIRECTION OF
KEITH HOLMES
ENGINEER OF RECORD
DATE

DESIGNED KH DATE JUNE, 2017
CHECKED JJ DATE JUNE, 2017
DRAWN SH DATE JUNE, 2017
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# APPENDIX

# D

## HYDRAULIC IMPACT ASSESSMENT

# APPENDIX

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nhc
northwest hydraulic consultants ltd

NHC Ref. No. 3002614

20 July 2017

**MMM Group Limited**
1045 Howe St #700
Vancouver, BC
V6Z 2A9

**Attention:** **Keith Holmes, P.Eng.**
Manager, Vancouver Bridges

**Via email:** Keith.holmes@wsp.com

**Re:** **Lions Gate Bridge and Ironworkers Memorial Bridge Vessel Collision Study**
**Lions Gate Bridge Concept Hydraulic Impact Assessment**

Dear Mr. Holmes:

This letter report presents the details of the study of hydraulic impacts of the proposed vessel collision mitigations structure on the south pier of the Lions Gate Bridge in Burrard Inlet, Vancouver.

# 1 INTRODUCTION

The British Columbia Ministry of Transportation and Infrastructure (MOTI) is undertaking a review and risk assessment of vessel impact issues for the 01481 Lions Gate Bridge (LGB) at First Narrows and the 01459 Ironworkers Memorial Bridge at Second Narrows in Vancouver's Burrard Inlet Harbour. A hydrotechnical analysis of the proposed physical vessel impact mitigation concept was conducted by Northwest Hydraulic Consultants Ltd. (NHC), and this report presents our preliminary findings and discusses potential implications for the LGB mitigation concept.

# 1 LGB VESSEL COLLISION PROTECTION CONCEPT

The concept evaluated is referred to as "16 m Berm Concept". The concept plan view and section view of the 16 m Berm Concept received from MMM Group Limited WSP on May 3, 2017 are reproduced in **Figure 1** and **Figure 2**.

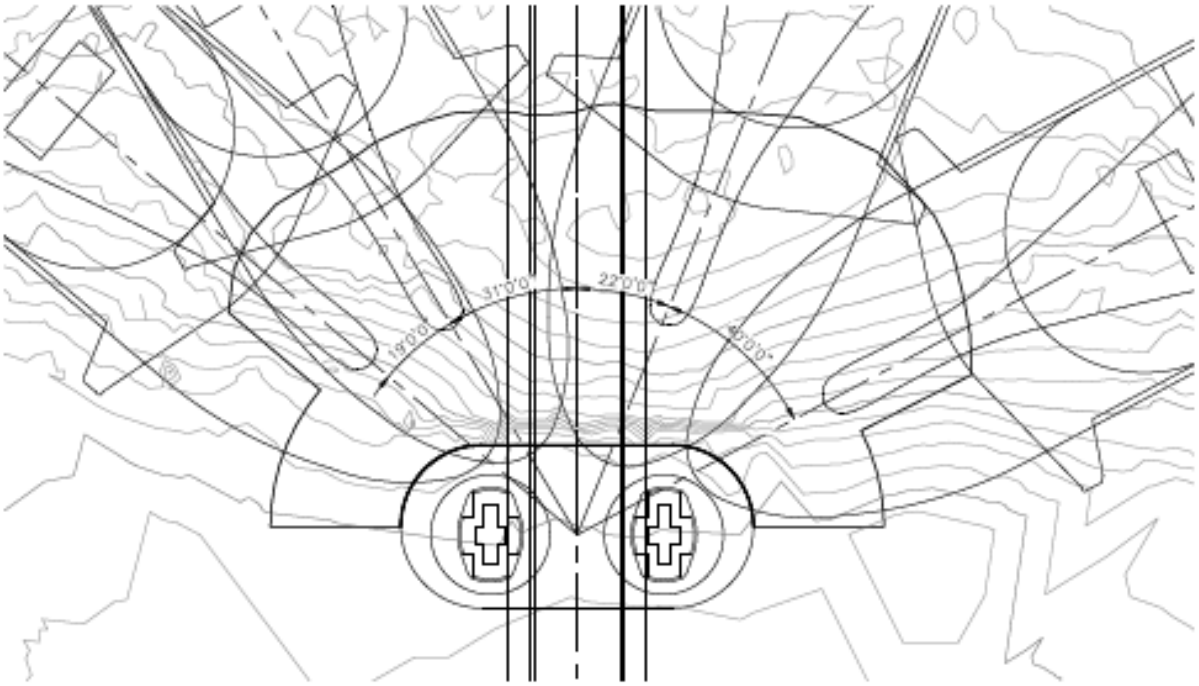

**Figure 1. LGB Vessel Collision Protection Concept – Plan View.**

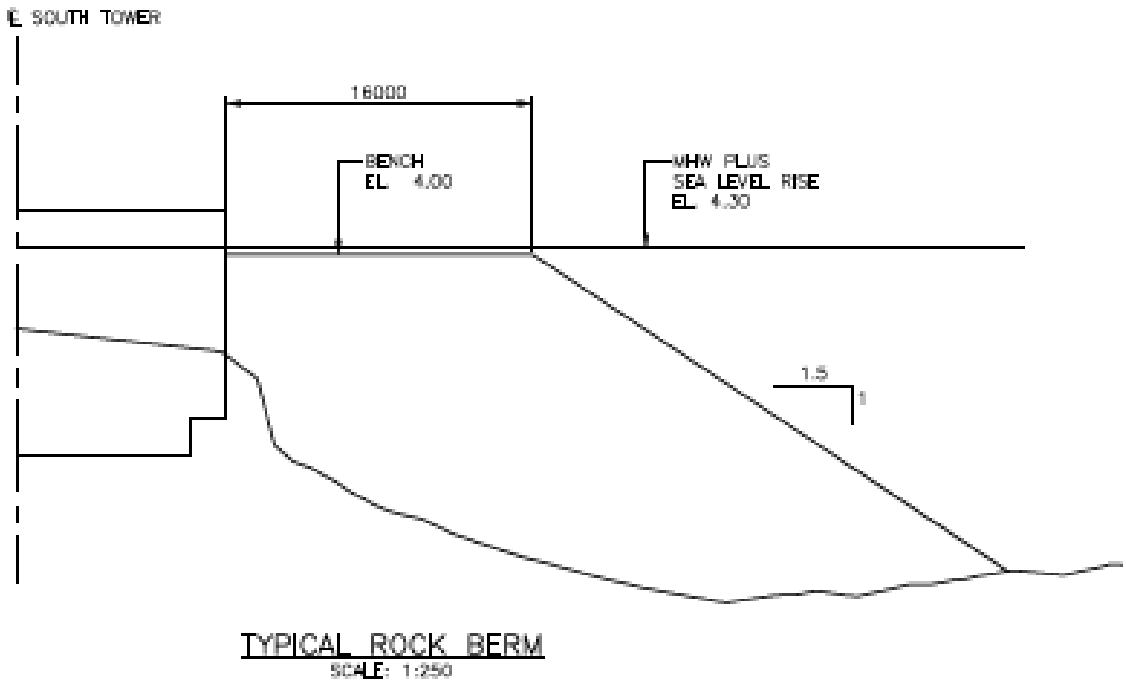


**Figure 2. LGB Vessel Collision Protection Concept –Section View.**

# 2 MODEL METHODOLOGY

A hydrodynamic model of the Burrard Inlet encompassing English Bay, Vancouver Harbour, and Indian Arm was developed to simulate the hydraulic effects that are expected to occur with the proposed physical mitigation concept. The model extent is shown in **Figure 3**. The model was developed using Delft3D, a 3D hydrodynamic model which calculates non-steady flow and transport phenomena that result from tidal and river flow forcing on a rectilinear or a curvilinear grid. Delft3D uses a finite difference scheme that numerically solves the horizontal momentum equation and includes discharge sources. The equations and model description are provided in detail in Lesser et al. (2014).

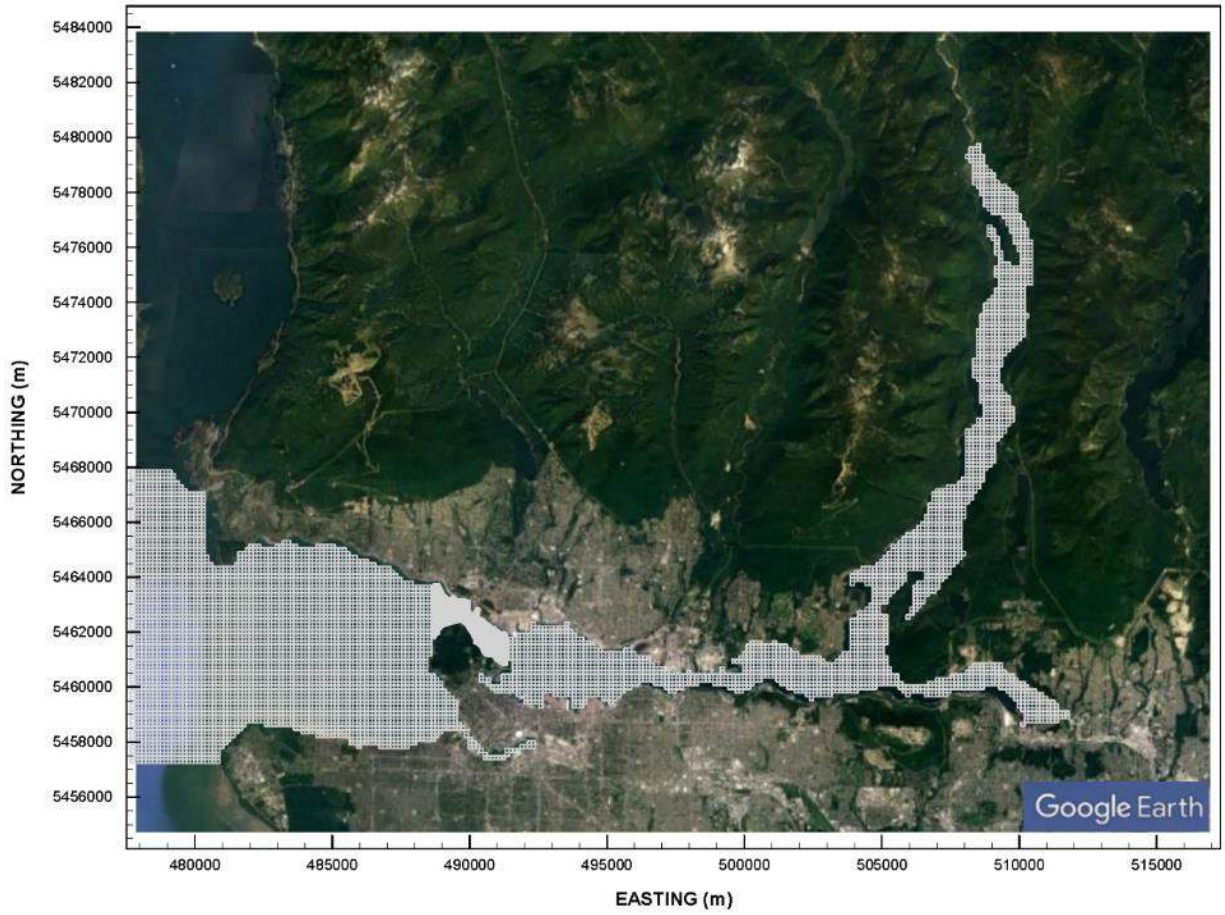


**Figure 3. Burrard Inlet model grids**

The Burrard Inlet model consists of three, 2-way coupled domains with progressively fining resolution. The finest horizontal grid resolution is near the First Narrows crossing where grid size is 5 m. In the vertical direction, the models consist of 15 sigma layers.

Tides are simulated with amplitudes and phases of 16 locally-dominant tidal constituents along the open ocean boundary (Point Atkinson). The bathymetry for the models is derived using datasets from CHS hydrographic charts as well as available Vancouver Fraser Port Authority (VFPA) survey data.

## 2.1 MODEL VALIDATION

The model was validated against water level at Vancouver Harbour and against 1981 Vancouver Harbour Tidal Current Atlas (VHTC). **Figure 4** shows the model output two hours before a turn to ebb. Vectors are shown with 200 m spacing. **Figure 5** shows the corresponding figure from the 1981 VHTC. The model captures the three eddies just east of Second Narrows Bridge as well as the eddy in the northern portion of Vancouver Harbour. The velocity magnitude generally agrees well. **Figure 6** shows the model output one hour after turn to ebb. **Figure 7** shows the corresponding figure from the 1981 VHTC. The modelled velocity magnitude and pattern between the two figures are similar.

The results show that the model is capable of reproducing similar velocity magnitude and pattern against 1981 VHCA.

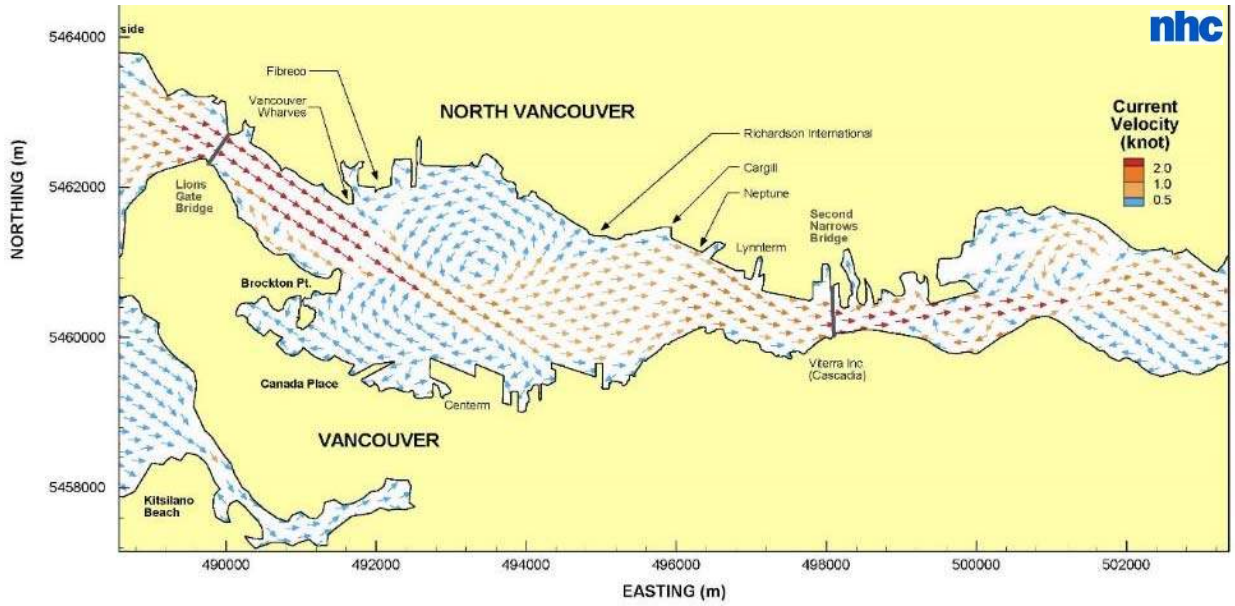


**Figure 4. Two hours before turn to ebb – Burrard Inlet model output**

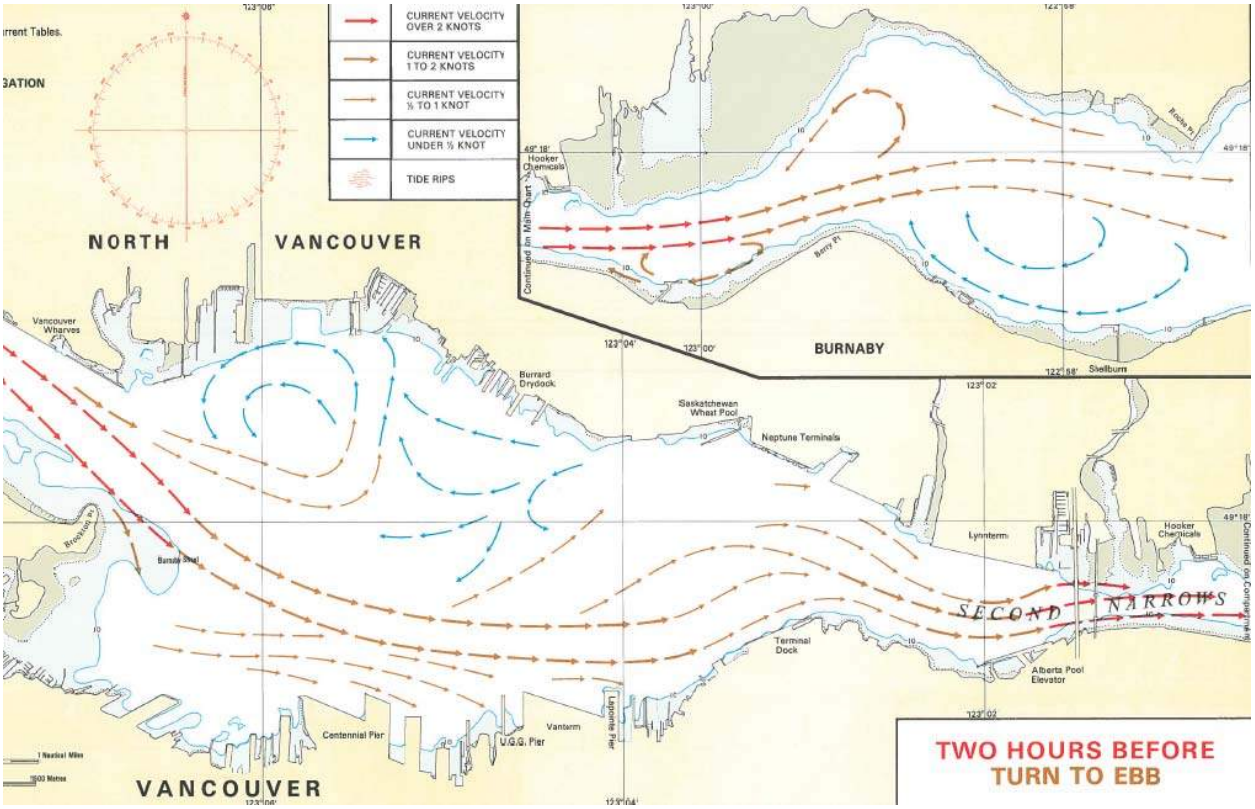


**Figure 5. Two hours before turn to ebb – reproduced from 1981 CHS VHTC**

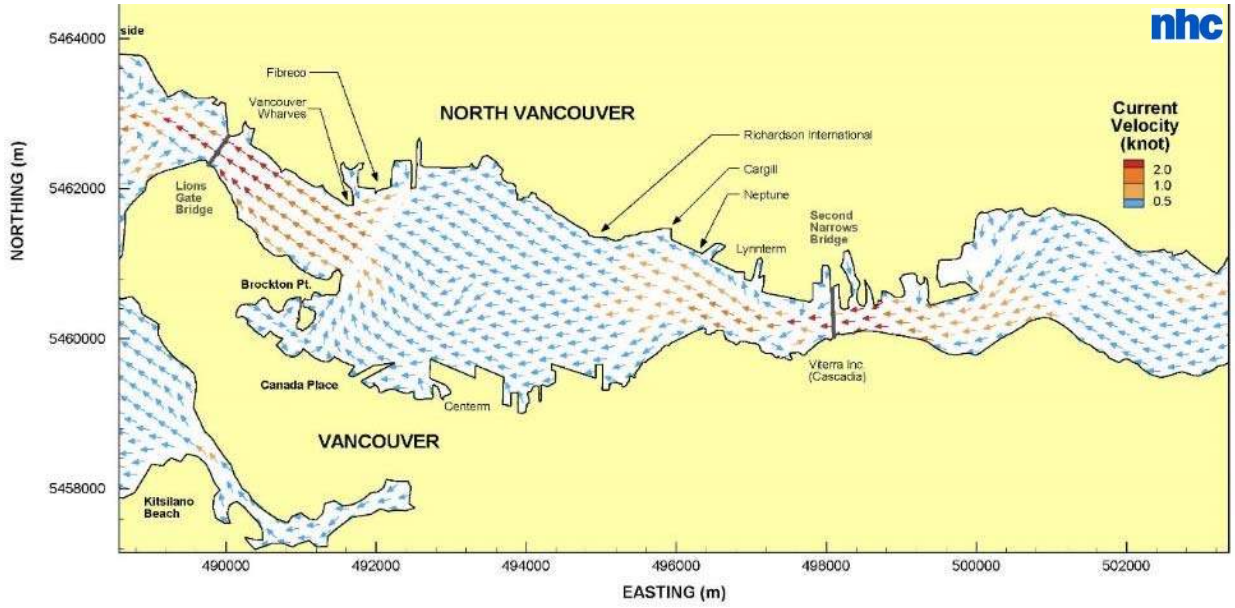


**Figure 6. One hour after turn to ebb – Burrard Inlet model output**

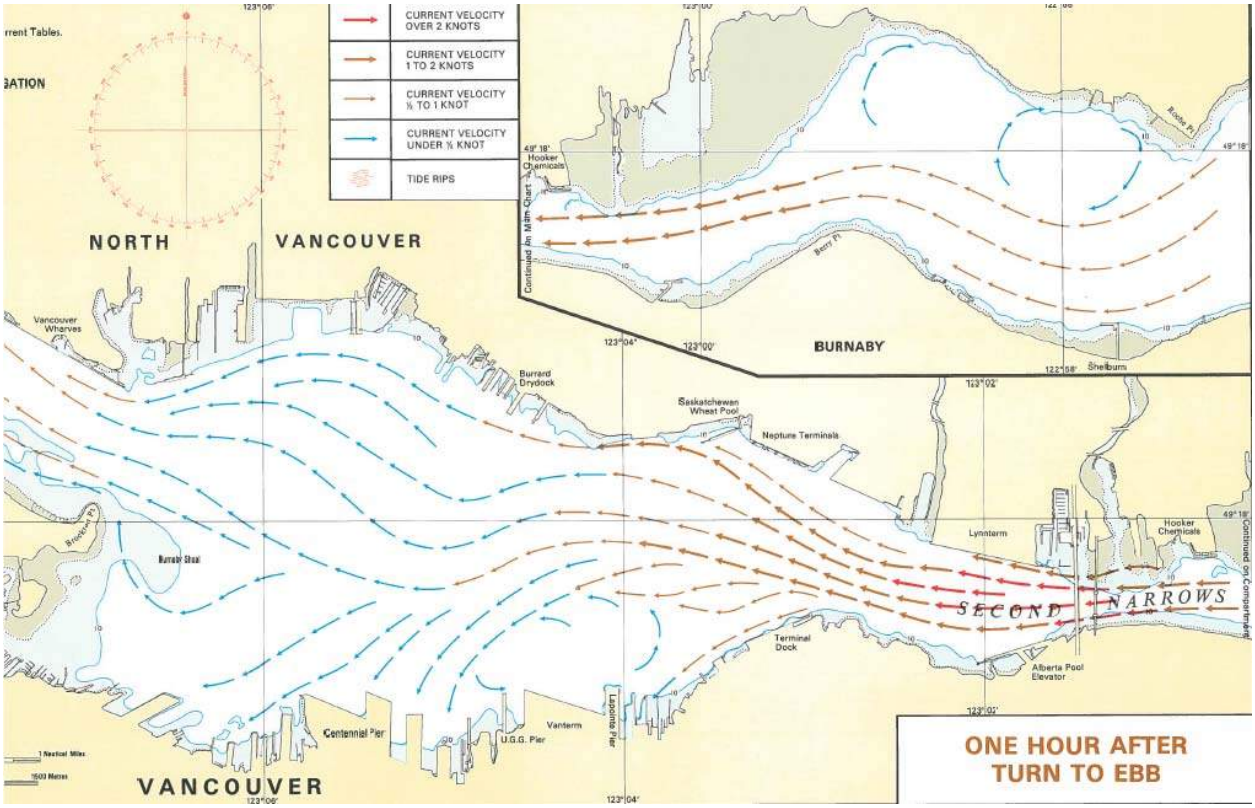


**Figure 7. One hours after turn to ebb – reproduced from 1981 CHS VHTC**

## 2.2 DESIGN EVENT SELECTION

Tides at Vancouver Harbour are mixed with mean Higher High Water value of 4.4 m, mean Lower Low Water value of 1.1 m and mean tidal range of 3.3 m. Two months of predicted hourly tidal elevations at Vancouver Harbour are shown in **Figure 8**, illustrating the biweekly tidal variability at Vancouver Harbour.

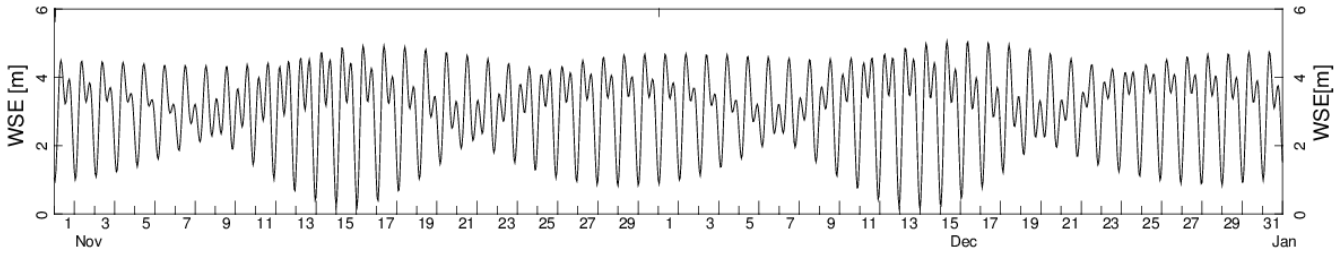


**Figure 8. Predicted tides at Vancouver Harbour from November 1 to December 31, 2012.**

The key hydraulic design consideration for the proposed mitigative concept is its impact on the navigability of waterways. Strong tidal currents occur during large tidal swings in Burrard Inlet and pose greater challenges for navigation. The November 14-15, 2012 tidal cycle (**Figure** 9) was selected for the assessment. Over this tidal cycle the water level decreased from 4.4 m Chart Datum (CD) to 0.3 m CD for

a tidal range of -4.1 m during ebb tide and increased from 0.3 m CD to 5.0 m CD for a tidal range of +4.7 m during flood tide. **Figure 10** shows a histogram of tidal range at Vancouver Harbour station between 1940 and 2014. The figure shows that tidal range less than -4.1 m occurred about 1.5% of the time and tidal range exceeded +4.7 m about 0.5% of the time.

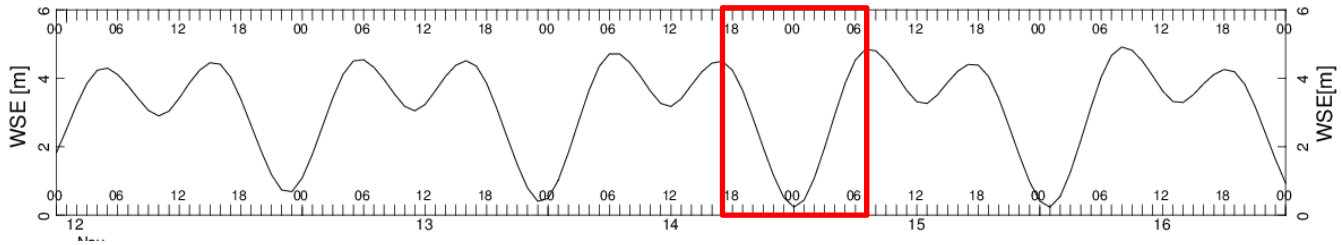


**Figure 9. Tidal conditions for the design simulation period of November 14-15, 2012**

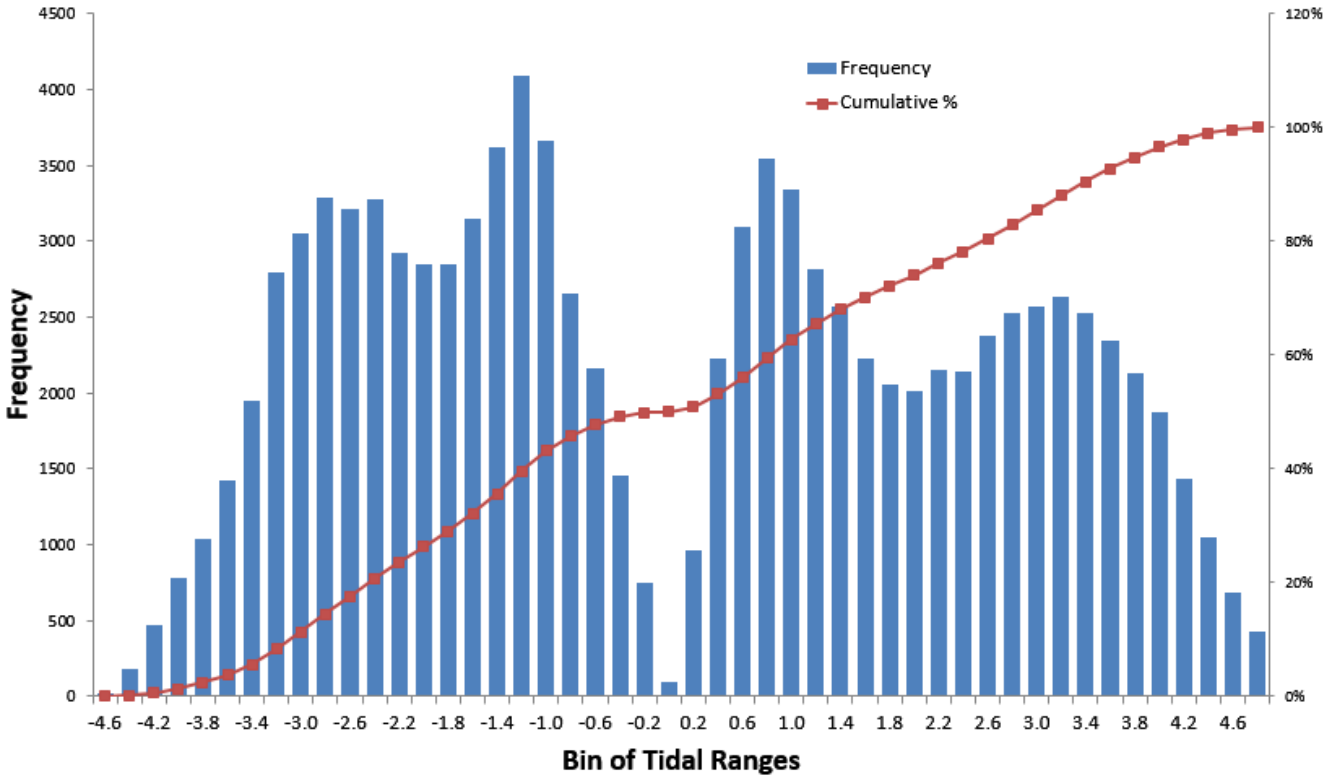


**Figure 10. Vancouver Harbour Tidal range histogram.**

# 3 HYDRAULIC ANALYSIS

To evaluate the potential hydraulic impact of the proposed mitigation concept, current distributions at surface, El. -5 m CD and at -10 m CD during the November 14-15, 2012 tidal cycle were evaluated.

## 3.1 EBB TIDE CONDITIONS

**Figure 11** and **Figure 12** show the surface current velocities for the existing conditions and with mitigation concept near the time of maximum ebb at 21:00 on November 14th, 2012. The contour colouring indicates the flow velocity. The figures show that the surface current at the First Narrows crossing during the modelled ebb tide conditions is relatively uniform across the crossing with magnitude of about 2.5 m/s.

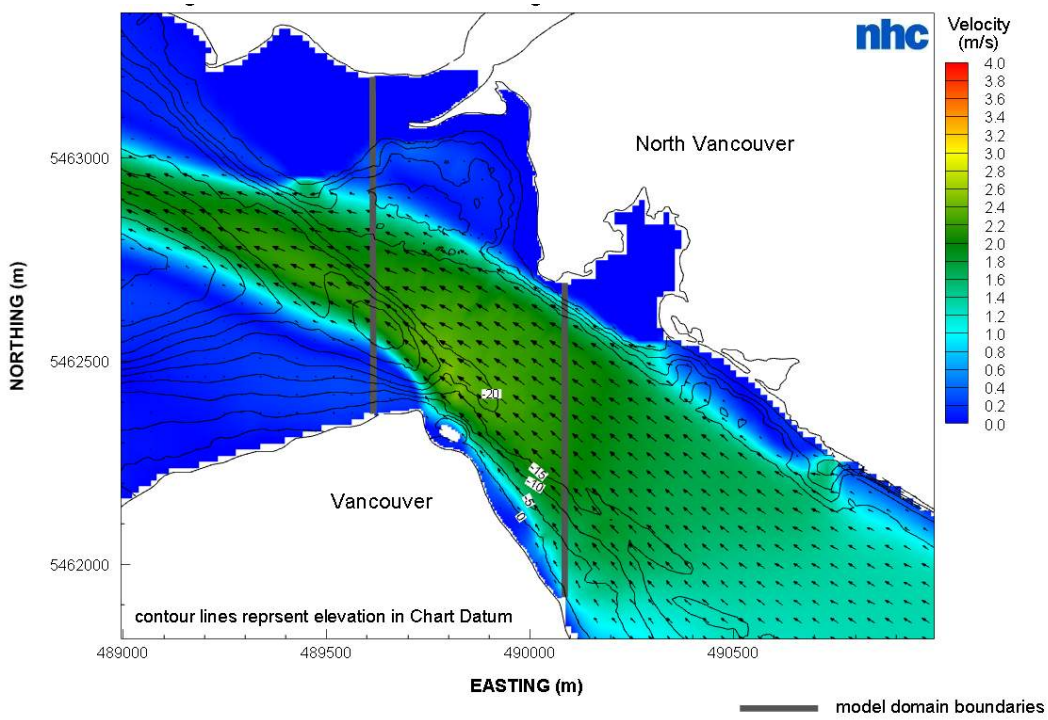


**Figure 11. Surface velocities during ebb tide – Existing Conditions**

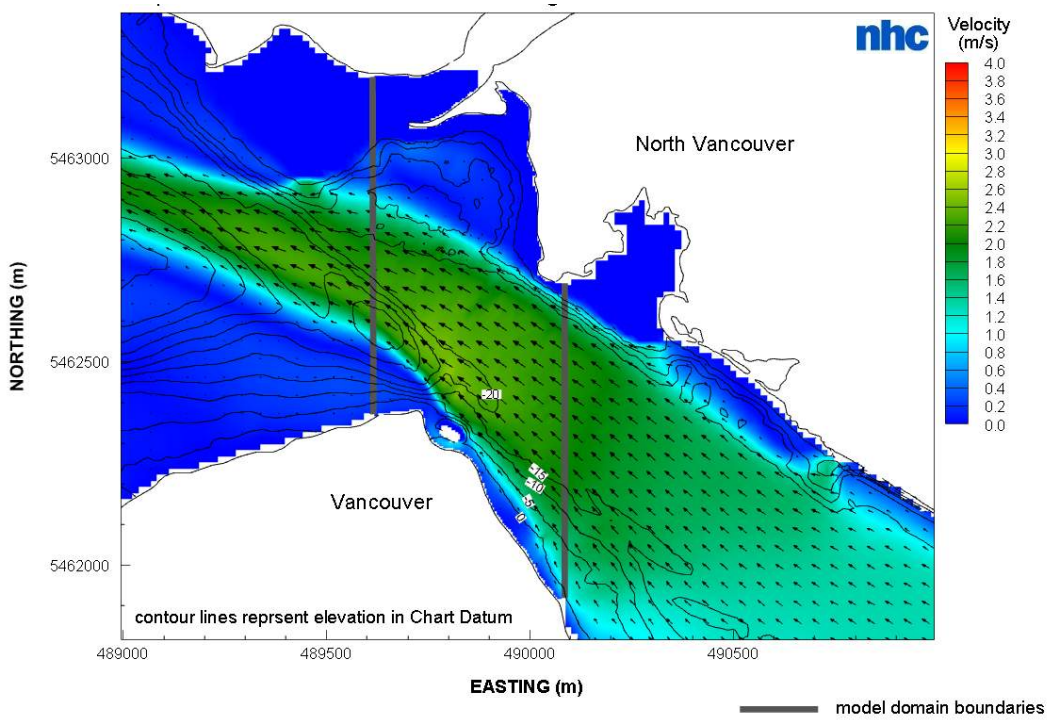


**Figure 12. Surface velocities during ebb tide – Proposed Conditions**

To better visualize the difference between the existing conditions and with concept conditions, surface velocity difference map was prepared and presented in **Figure 13** (with concept subtracts existing conditions). The yellow and red shading indicates regions experiencing velocity increase under the concept conditions and the blue shadings represent regions experiencing velocity decrease. Velocity difference of less than ±0.10 m/s is considered not significant.

The results show that:

1. The proposed mitigation concept shifts the current northward resulting in slight velocity increase (< 0.2 m/s) along the north side of the crossing. The extent of the impact is about 1,000 m.
2. The region leeward of the proposed mitigation concept experiences velocity reduction by up to 1 m/s. The extent of this impact is about 1,000 m.
3. The region between the South Tower and the shoreline experiences velocity increase of about 0.7 m/s.

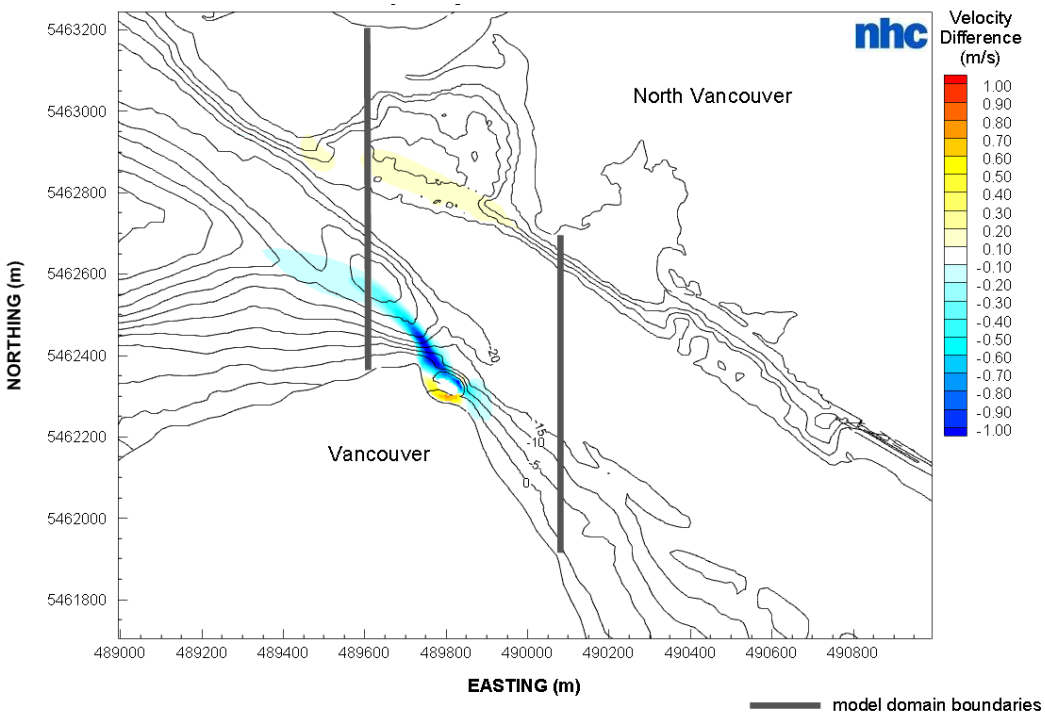


**Figure 13. Differences in surface velocity during ebb tide**

**Figure 14** and **Figure 15** show the differences in velocity between existing conditions and with mitigation concept at El. -5 m CD and El. -10 m CD. The results show that greatest impact occur at the surface and decreases with depth.

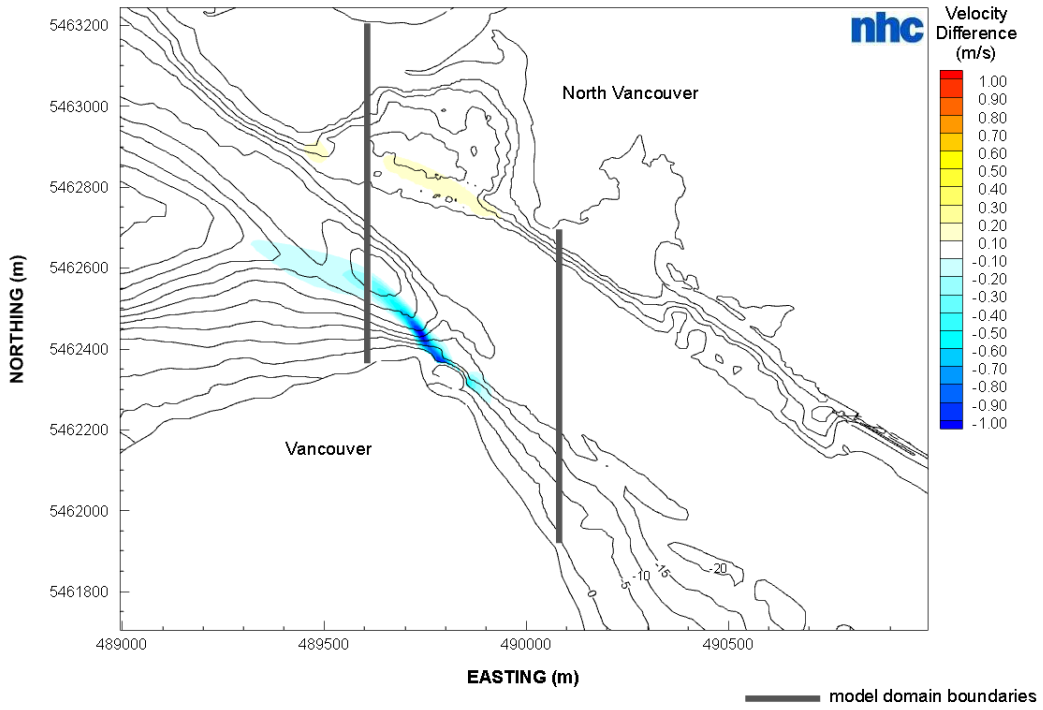


**Figure 14. Differences in velocity at El. -5 m CD during ebb tide**

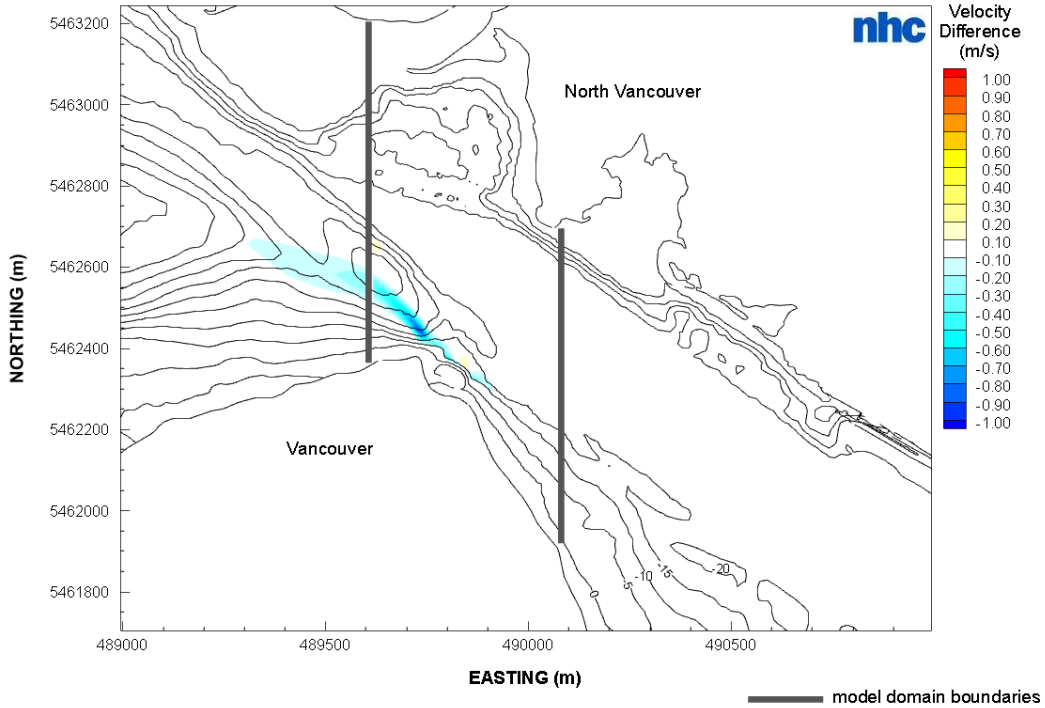


**Figure 15. Differences in velocity at El. -10 m CD during ebb tide**

## 3.2 FLOOD TIDE CONDITIONS

**Figure 16** and **Figure 17** show the surface current velocities for the existing conditions and with mitigation concept near the time of maximum flood at 4:00 on November 15th, 2012. The contour colouring indicates the flow velocity. The general surface current at the First Narrows crossing during the modelled flood tide conditions is at about 2 m/s. Higher velocity of 2.8 m/s is predicted along the south shore.

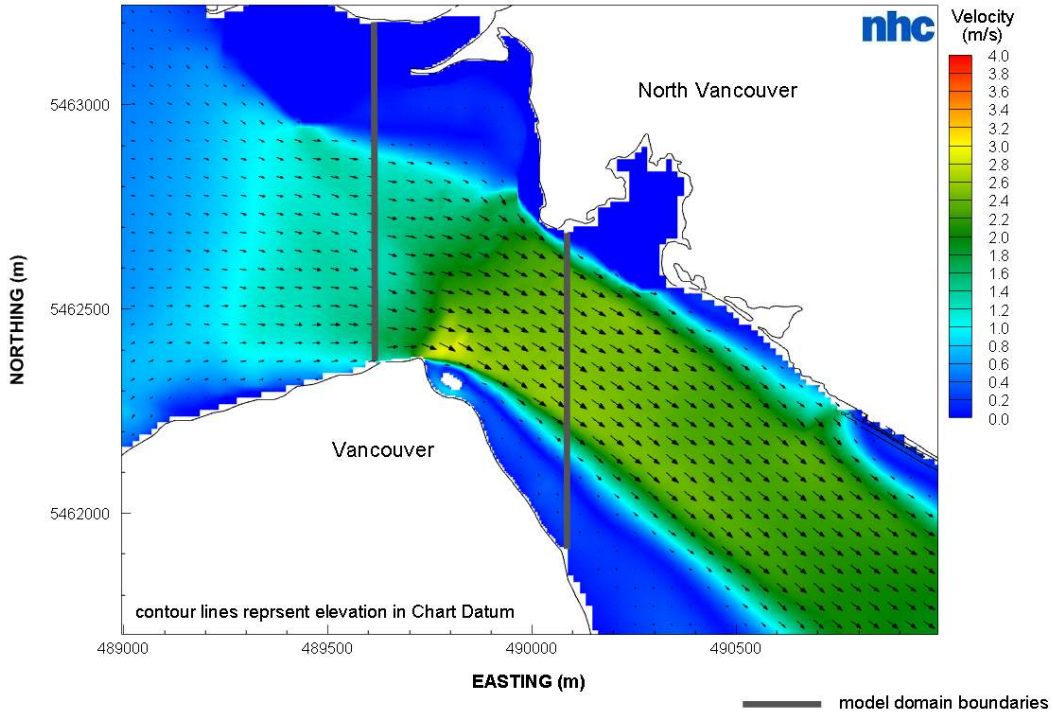


**Figure 16. Surface velocities during flood tide – Existing Conditions**

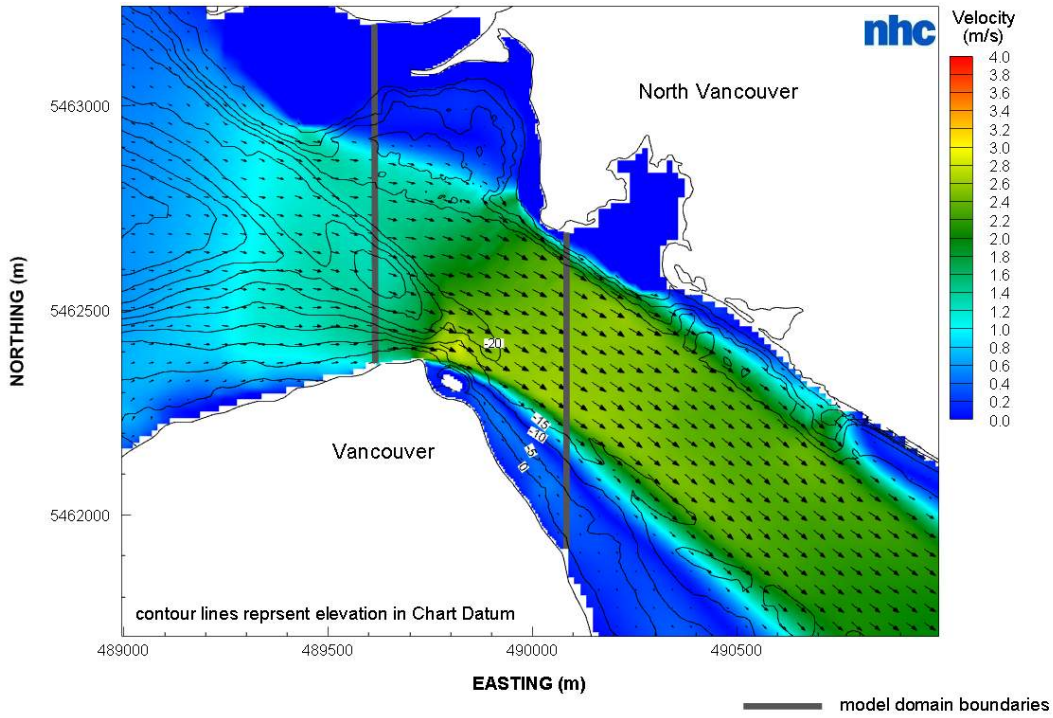


**Figure 17. Surface velocities during flood tide – Proposed Conditions**

To better visualize the difference between the existing conditions and with concept conditions, surface velocity difference map was prepared and presented in **Figure 18** (with concept subtracts existing conditions).

The yellow and red shading indicates regions experiencing velocity increase under the with concept conditions and the blue shadings represent regions experiencing velocity decrease. Velocity difference of less than ±0.10 m/s is considered not significant.

The results show that:

1. The proposed mitigation concept alters the tidal current northward. The increase in velocity in the channel is less than 0.1 m/s and therefore is illustrated as 'no change' in **Figure 18**.
2. The region leeward of the proposed mitigation concept experiences velocity reduction by up to 0.5 m/s. The extent of this impact is about 1,000 m.
3. The proposed mitigation concept increases the magnitude of the back eddy circulation in the near bank region by about 0.3 m/s. The extent of this impact is about 500 m.
4. The region between the South Tower and the shoreline experiences velocity reduction of about 0.7 m/s.

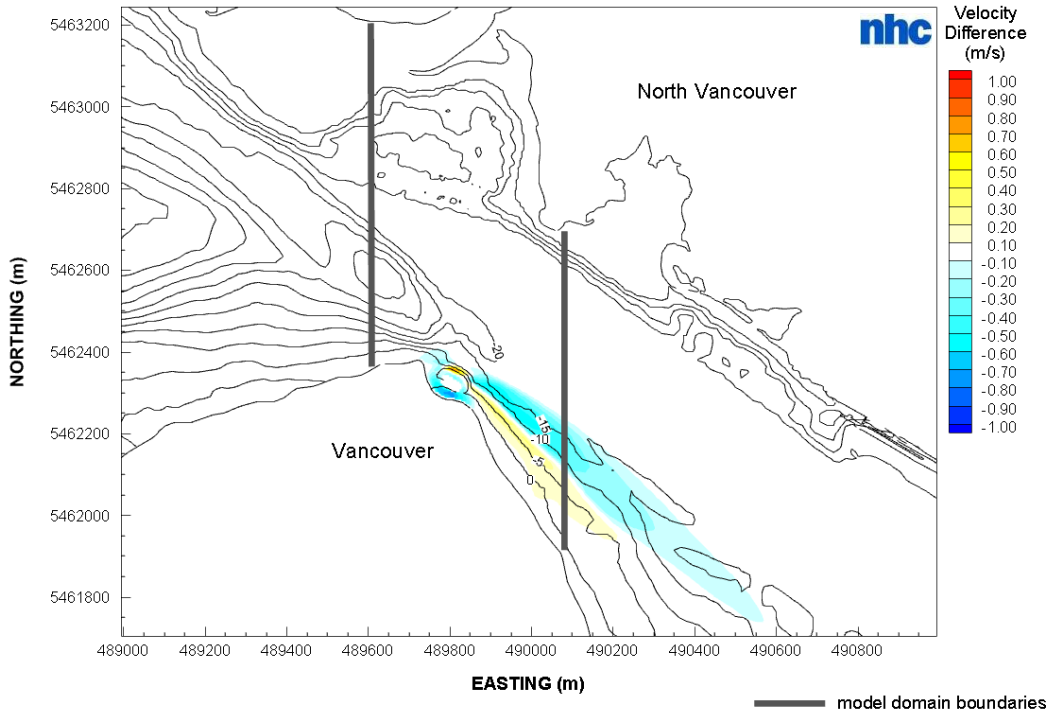


**Figure 18. Differences in surface velocity during flood tide**

**Figure 19** and **Figure 20** show the differences in velocity at El. -5 m CD and El. -10 m CD. Similar to the findings from the ebb tide conditions, the results show that greatest impact occur at the surface and decreases with depth.

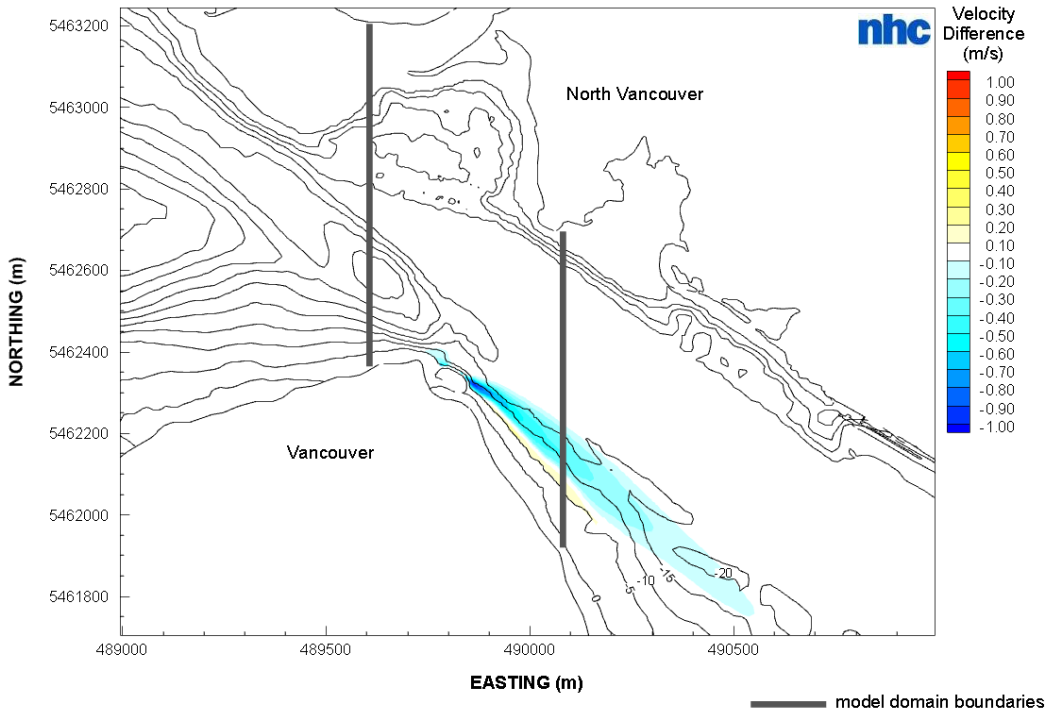


**Figure 19. Differences in velocity at El. -5 m CD during flood tide**

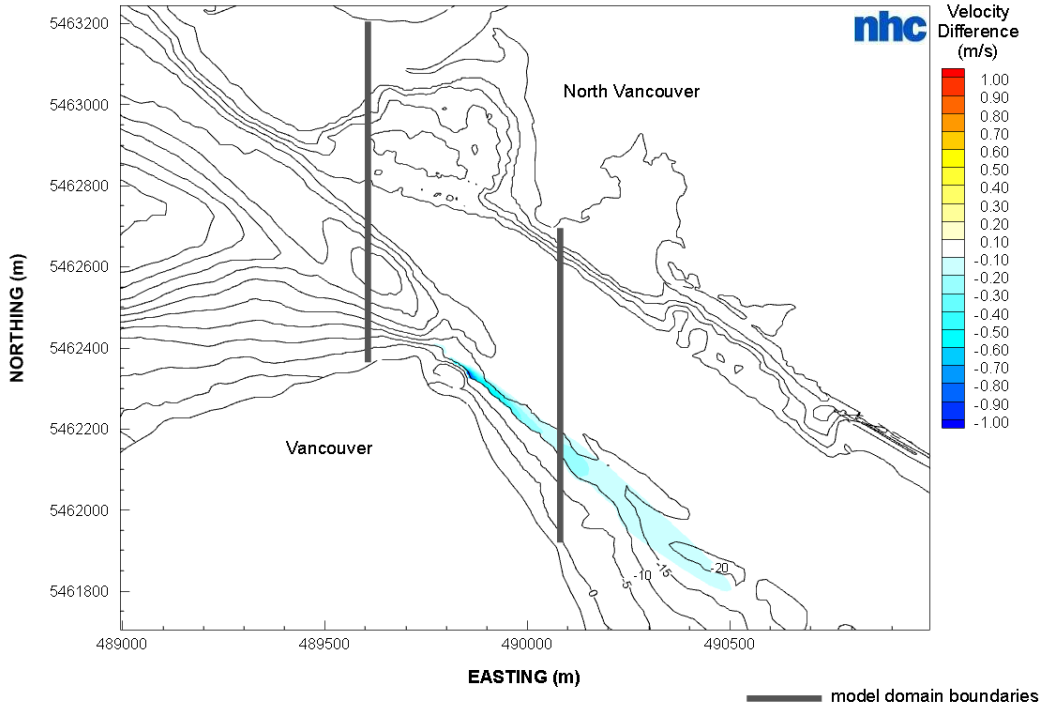


**Figure 20. Differences in velocity at El. -10 m CD during flood tide**

# 4 CONCLUSIONS

The study shows that:

1. The extent of the hydraulic impact due to the proposed mitigation concept is about 2,000 m – 1,000 m west and 1,000 east of LGB.
2. The proposed mitigation concept results in greater hydraulic impact in the channel during the ebb tide than during the flood tide.
3. Maximum velocity increase due to the proposed mitigation concept is about 0.7 m/s and occurs during ebb tide and in the region between South Tower and the shoreline.
4. Maximum velocity reduction due to the proposed mitigation concept is about 1 m/s and occurs during ebb tide and in the region leeward of the proposed mitigation concept.

# 5 CLOSURE

We hope this work and report meets your current needs. If you have any questions or would like to further discuss these findings, please contact Edwin Wang at our North Vancouver office at (604) 980-6011 or by email (ewang@nhcweb.com).

Sincerely,

**Northwest Hydraulic Consultants Ltd.**

Prepared by:

Edwin Wang, P.Eng.
Hydrotechnical Engineer

Reviewed by:

Barry Chilibeck, P.Eng.
Principal

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# APPENDIX

# E

## COST ESTIMATE TABULATION

# APPENDIX

**01481 Lions Gate Bridge** Preliminary Cost Estimate

*Vessel Collision Risk Migitation Measures*

## OPTION 3a: ROCK FILL PROTECTION BERM CONCEPT

| Item | Description | Unit | Quantity | Unit Price | Total | Notes |
|---|---|---|---|---|---|---|
| **1** | **Investigation, Engineering, Permitting, Engagement** | | | | | |
| 1.1 | Geophysical Overwater Survey (Sub-Bottom Profiling) | LS | 1 | $25,000 | $25,000 | 0% of Estimated Capital Costs |
| 1.2 | Sonic Test Holes (2) | LS | 1 | $100,000 | $65,000 | 1% of Estimated Capital Costs |
| 1.3 | Detailed Analytical Confirmation, Design, Contract Documents (geotech, structural, hydrotechnical) | LS | 1 | $250,000 | $250,000 | 3% of Estimated Capital Costs |
| 1.4 | Environmental Permitting | LS | 1 | $500,000 | $500,000 | 7% of Estimated Capital Costs |
| | **Sub-Total (Investigation, Engineering, Permitting, Engagement):** | | | | **$840,000** | |
| **2** | **Physical Mitigation Measures (Estimated Capital Costs)** | | | | | |
| 2.1 | Mobilization, Survey Control, Overhead Support | LS | 1 | $1,500,000 | $1,500,000 | 20% of Estimated Capital Costs |
| 2.2 | Quarry Rock Riprap (1200 Minus, Supply, Transport, Placement) | $m^3$ | 15,000 | $250 | $3,750,000 | Installed wtih clamshell |
| 2.3 | Quarry Tailings (300-450 Minus, Supply, Transport, Placement) | $m^3$ | 25,000 | $90 | $2,250,000 | Includes some waste; 2/3 installed with dump barge; 1/3 installed with clamshell |
| 2.4 | Navigation Beacon | Each | 1 | $150,000 | $150,000 | Type and size to be confirmed at detailed design. |
| | **Sub-Total (All Construction Works):** | | | | **$7,650,000** | |
| **3** | **Other Costs During Construction** | | | | | |
| 3.1 | Environmental Mitigation and Compensation | LS | 1 | $1,000,000 | $1,000,000 | 13% of Estimated Capital Costs |
| 3.2 | Engineering and Contract Administration Services during Construction | months | 12 | $45,000 | $540,000 | 7% of Estimated Capital Costs |
| | **Sub-Total (All Construction Works):** | | | | **$1,540,000** | |
| **4** | **Total** | | | | | |
| | **Sub-Total (All Construction Works, Engineering, Approvals)** | | | | **$10,030,000** | |
| | **Contingency:** | | | 50% | $5,015,000 | |
| | **Total:** | | | | **$15,045,000** | |

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**01481 Lions Gate Bridge** Preliminary Cost Estimate

*Vessel Collision Risk Migitation Measures*

## OPTION 3e: COMBI-WALL PROTECTION CONCEPT

| Item | Description | Unit | Quantity | Unit Price | Total | Notes |
|---|---|---|---|---|---|---|
| **1** | **Investigation, Engineering, Permitting, Engagement** | | | | | |
| 1.1 | Geophysical Overwater Survey (Sub-Bottom Profiling) | LS | 1 | $25,000 | $25,000 | 0% of Estimated Capital Costs |
| 1.2 | Sonic Test Holes (2) | LS | 1 | $100,000 | $65,000 | 0% of Estimated Capital Costs |
| 1.3 | Detailed Analytical Confirmation, Design, Contract Documents (geotech, structural, hydrotechnical) | LS | 1 | $500,000 | $500,000 | 4% of Estimated Capital Costs |
| 1.4 | Environmental Permitting | LS | 1 | $500,000 | $500,000 | 4% of Estimated Capital Costs |
| | **Sub-Total (Investigation, Engineering, Permitting, Engagement):** | | | | **$1,090,000** | |
| **2** | **Physical Mitigation Measures (Estimated Capital Costs)** | | | | | |
| 2.1 | Mobilization, Survey Control, Overhead Support | LS | 1 | $2,000,000 | $2,000,000 | 15% of Estimated Capital Costs |
| 2.2 | Coated Steel Pipe Piles - Supply | m | 900 | $1,825 | $1,642,500 | Based on 914 dia x 25 wall thickness |
| 2.2 | Coated Steel Pipe Piles - Install | each | 42 | $50,000 | $2,100,000 | Based on 8m embedment: 6 m socket + 2m overburden; Includes collection of drill cuttings. |
| 2.3 | Coated Sheet Piles (Main Wall) - Supply and Install | $m^2$ | 900 | $1,510 | $1,359,000 | |
| 2.4 | Coated Sheet Piles (Anchor Wall) - Supply and Install | $m^2$ | 350 | $900 | $315,000 | Double-Corrosion Protected |
| 2.5 | DWIDAG Tie Rods - Supply, Install, Misc Hardware - Supply and Install | m | 840 | $1,000 | $840,000 | DCP |
| 2.6 | Rockfill - Supply and Install | $m^3$ | 25,000 | $100 | $2,500,000 | Quarry fines and tailings |
| 2.7 | Pile Concrete Infill - Supply and Install | $m^3$ | 528 | $3,000 | $1,583,001 | Recommended for corrosion protection |
| 2.8 | Reinforced Concrete Coping Beam - Supply and Install | m | 110 | $10,000 | $1,100,000 | 2x2 Section. Includes concrete, rebar, formwork and precast install |
| 2.9 | Navigation Beacon - Supply and install | Each | 2 | $25,000 | $50,000 | Type and size to be confirmed at detailed design. |
| | **Sub-Total (All Construction Works):** | | | | **$13,489,501** | |
| **3** | **Other Costs During Construction** | | | | | |
| 3.1 | Environmental Mitigation and Compensation | LS | 1 | $750,000 | $750,000 | 6% of Estimated Capital Costs |
| 3.3 | Engineering and Contract Administration Services during Construction | months | 24 | $45,000 | $1,080,000 | 8% of Estimated Capital Costs |
| | **Sub-Total (All Construction Works):** | | | | **$1,830,000** | |
| **4** | **Total** | | | | | |
| | **Sub-Total (All Construction Works, Engineering, Approvals)** | | | | **$16,409,501** | |
| | **Contingency:** | | | 50% | $8,204,750 | Far higher risks, compared to rock fill berm concept |
| | **Total:** | | | | **$24,614,251** | |

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