

# Risk Assessment for Fremantle Traffic **Bridge Design Options**

for

Main Roads WA

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1.0 EXECUTIVE SUMMARY



## **EXECUTIVE SUMMARY**

## 1 Summary

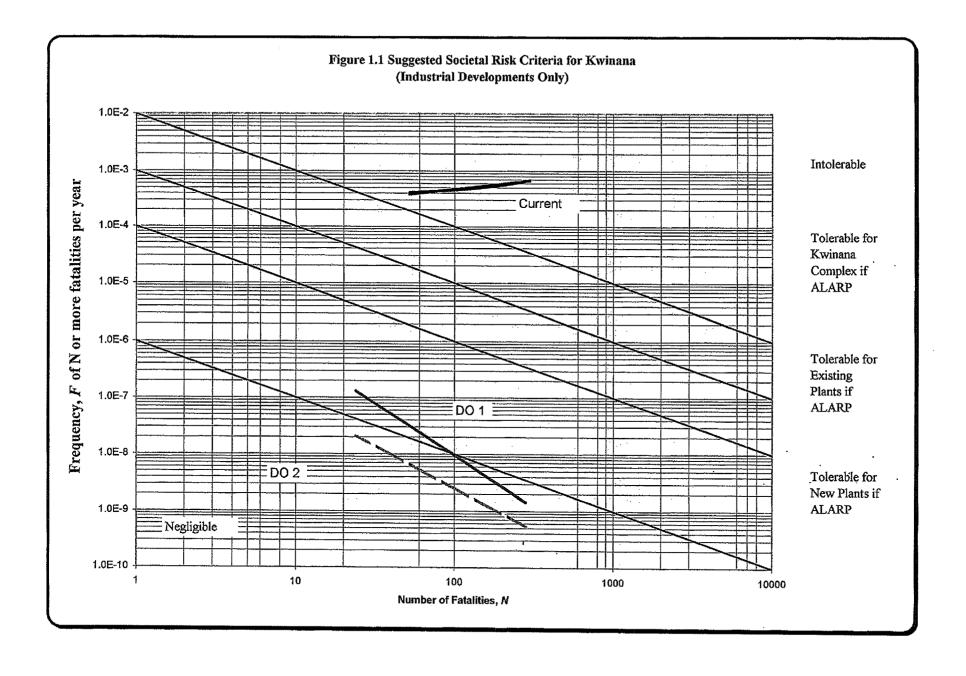
The Fremantle Traffic Bridge was constructed in 1938 and carries Queen Victoria Street from Stirling Highway over the Swan River upstream of Fremantle harbour. The bridge forms one of the important arteries in Perth's road system supporting an average of 30,100 vehicles per day among other utility services such as water, gas, electricity, fuel oil and telecommunication links. The river beneath is used by river traffic for accessing the ocean or returning from the port. Vessels that pass through the bridge range from small privately owned yachts to passenger ferries up to 370 tonnes.

This report assesses the risk of two proposed design options for the Fremantle Traffic Bridge. The design options identified in a previous study of the bridge as risk reduction measures [1] are as follows:

- Design option 1 (DO1): Addition of Dolphin and Fender Strengthening
- Design option 2 (DO2): Widening of the Navigation Span

The design options are aimed at reducing the risk of bridge structural failure from boat collision. Table 1.1 shows advantages and disadvantages offered by each proposed option. The risk analysis reached the following conclusions:

- Both design options conform to the accepted criteria set by Austroads and the US Department of Transportation.
- Design option 1 the addition of dolphins to the piers will increase the likelihood of collision as a result of movement restrictions during passage, especially on entry and exit. The narrow middle span, with maximum clearance and favoured by most skippers due to varying tidal heights, will become more hazardous as the manoeuvring distance between the Traffic and Railway bridges is reduced.
- By inspection, although not quantified, alignment of the rail and traffic bridges will reduce the risks associated with manoeuvring vessels through this area.
- The overall cumulative frequency of collision resulting in a fatality for design option 1 is  $5.5 \times 10^{-7}$  pa and for design option 2 is  $1.0 \times 10^{-7}$  pa.
- The current cumulative frequency of glancing collisions with the navigational spans is 1.6 x 10<sup>-4</sup> pa. The overall cumulative frequency of a glancing collision DO 1 is 2.7 x 10<sup>-4</sup> pa, an increase of 72% and for DO 2 is 4.1 x 10<sup>-5</sup> pa, a reduction of 74%.
- From structural analyses vessel sizes of greater than 155 tonnes will cause structural failure of the bridge on collision with the **non navigation spans** at 4 knots or greater.
- From structural analyses vessel sizes of greater than 45 tonnes will cause structural failure of the bridge on collision with the **non navigation spans** at 10 knots or greater.
- The risks to the public resulting from design option 1 are tolerable / negligible when compared to risk criteria for industrial sites (Figure 1.1).
- The risks to the public resulting from design option 2 are negligible when compared to risk criteria used for industrial sites (Figure 1.1). Risk criterion for public areas may generally be considered stricter than those presented for industrial developments.





# **EXECUTIVE SUMMARY**

Table 1.1 Risk Related Advantages and Disadvantages of Design Options

Task		Design Option 1	Design Option 2
		Dolphins and fender strengthening	Widening the Navigation span
Approach to the bridge	+ ve	Protect timber structure from possible vessel collision Control the tidal flows through the bridge better.	Presents a less hazardous approach to and through the bridge, as the spans are 34.75m wide. Approx 3 times the width of the widest boat.  The jetty on approach from downstream will not cause unnecessary manoeuvring of vessels due to better bridge alignment.
From up/down river	- ve	Placement of the jetty on approach from downstream causes unnecessary manoeuvring of vessels as they require approx. 100 metres of approach way.	None identified
Lining up with the bridge	+ ve	None identified	Due to the extra width, winds and currents moving the boat will not force skippers into sudden movements.
	- ve	The piers are extended by an additional 5.5m on each side of the bridge, highlighting the fact of maintaining a good line for safe passage.  Vessels stopping at the East Street Jetty prior to the bridge, will need to make more movements to navigate the bridge after setting passengers down.	None identified
Travelling through the bridge, (currents, wind)	+ ve	The fenders are strengthened to protect the structure from collisions.	Structure is protected from collision The boats have a greater amount of width clearance through the bridges, thus reducing fender damage and chance of structure collision.
	- ve	The length of piers are increased in some case by an additional 11m. This will lead to regular glancing of fenders and increased maintenance costs.  There is a greater possibility of causing damage to vessels on the River.	Currently skippers navigate through the middle span during high tides. The removal of this guide will result in the need to be more aware of tide levels when navigating the Bridge.
Alignment on exit	+ ve	Structure is protected from collision	Structure is protected from collision A line can be taken to avoid sharp turns during bridge passage. The wider span allows a less hazardous line to be taken on passage through both the Traffic and Railway Bridge.
	- ve	From upstream passages the dog leg turn on the middle span is expected to significantly impair vessels navigating both bridges.  A considerable increase in bridge collision is expected to occur due to the reduced distance, tidal currents and wind conditions the vessels must navigate caused by the addition of dolphins.	None identified



#### **EXECUTIVE SUMMARY**

During the course of the risk assessment, vessel operators and Port Authority personnel were contacted for information. In discussions about the Fremantle Bridge, various suggestions were volunteered on how the bridge could be made inherently safer.

The suggestions were as follows:

- Addition of markers hanging from span entrances and exits to allow skippers to line up vessels properly.
- Addition of tide height markers on the bridges prior to the Fremantle Traffic Bridge. This
  allows skippers to get an accurate understanding of current tide heights rather than rely on
  Fremantle Port Authority.
- It was highlighted by various skippers that a significant number of private boat owners did
  not understand the rules of navigation, often causing frustration and extra hazards for
  other boat users. Perhaps a greater navigation awareness campaign could benefit all Swan
  River users.
- In order to reduce damage to boats and fendering, the addition of impact absorbing fenders was suggested.
- Addition of guiding piles to ensure vessels do not ever hit non navigation spans, and also guide vessels though the navigation channels.
- Ensure alignment of the Traffic and Railway Bridge if design option 2 is implemented.



2.0 INTRODUCTION



# INTRODUCTION

# 2 Fremantle Bridge Background

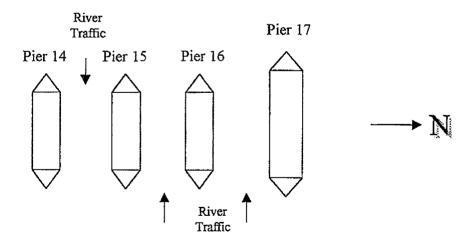
The Fremantle Traffic Bridge was constructed in 1938 and carries Queen Victoria Street from Stirling Highway over the Swan River upstream of Fremantle harbour. The bridge is one of the important arteries in Perth's road system supporting an average of 30,100 vehicles per day among other utility services, such as water, gas, electricity, fuel oil and telecommunication links. The river beneath is used by river traffic for accessing the ocean or returning from the port. Vessels that use the bridge range from small privately owned yachts to passenger ferries up to 370 tonnes. The bridge is predominantly made of timber, although the three navigational spans are steel beam with timber decking. A considerable amount of maintenance work has been carried out in the last twenty years to repair collision damage and maintain serviceability.

QEST Consulting Engineers have been commissioned by Main Roads West Australia (MRWA) to assess the risk of two separate design options on the Fremantle Traffic Bridge. The design options identified in a previous study of the bridge as risk reduction measures [1] are as follows:

- · Addition of Dolphin and Fender Strengthening
- Widening of the Navigation Span

The design options are aimed at reducing the risk of bridge structural failure from boat collision. The current arrangement of the Fremantle Traffic Bridge is shown in Figure 2.1.

Figure 2.1 Current Arrangement of Fremantle Traffic Bridge





## INTRODUCTION

## 2.1 Option 1 - Dolphin and Fender Strengthening

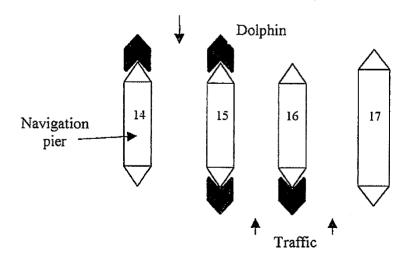
From the previous study completed on the bridge concerns were raised about the strength of the navigation span piers and protection provided by existing fenders if a head-on vessel collision occurred. The addition of dolphins and fender strengthening will be designed to provide ample protection for such a case. The piers to receive strengthening are detailed below in Table 2.1 and shown in Figure 2.2. Design general arrangement drawings can be seen in Appendix 1.

Table 2.1 Dolphin and Fender Strengthening

Pier No.	Description of surrounding area	Dolphin and fender strengthering
14	Located on the South of river	West side only
15	Separates the up and down river traffic	East and West sides
16	Separates two lanes of down river traffic	East side only
17	Located on the North of river	Concrete pier is deemed strong enough to withstand a head on impact

However with the addition of dolphins, passage through the navigation channel is extended by 5.5 metres either side of some piers. This increases the chance of glancing a fender on passage under the bridge and imposes greater restrictions on boat alignment with the Railway Bridge.

Figure 2.2 Design Option 1 for Fremantle Traffic Bridge



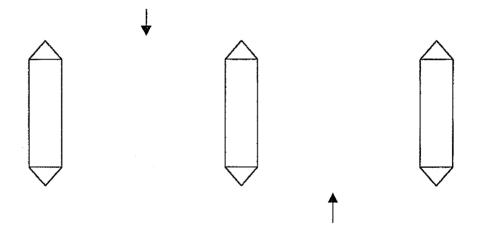


# INTRODUCTION

## 2.2 Option 2 - Widening of the Navigation Span

Currently the River traffic under the bridge operates as follows, vessels travelling down river pass through the navigation spans 15-16 and 16-17 depending on sea conditions (tide heights, current and wind). Traffic from Fremantle port into Perth passes through navigation span 14-15. Design option 2, widening the navigation spans, involves the removal of piers 13-18 and the installation of three new piers allowing wider spans. This would reduce the risk of boats colliding with the bridge, as the navigation spans would be considerably wider. The navigational line between the Railway Bridge and Fremantle Bridge would become significantly straighter. Design general arrangement drawings can be seen in Appendix 1.

Figure 2.3 Design Option 2 for Fremantle Traffic Bridge



#### 2.3 Study Objectives

The scope of the study is to identify the risk posed to the public from collision of various vessel sizes using the proposed design options of fendering and dolphin protection (DO1) and widening the navigation spans (DO2) for the Fremantle Bridge.

The principal objectives were as follows:

- Identify major hazards posed to the bridge in terms of structural integrity
- Calculate frequencies associated with each single scenario
- Quantify the overall risk levels for each scenario
- Examine the effectiveness of each design option
- · Recommend any further risk mitigation measures



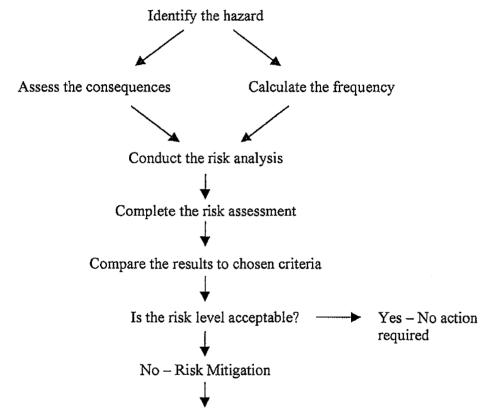
3.0 APPROACH



# 3 Methodology

## 3.1 Description

Previous studies and port records were analysed to determine the types of incidents that have occurred in the Fremantle Port, the Swan River and similar ports. The methodology employed in this risk assessment is summarised below.



Discuss effectiveness of each design option

In order to identify hazards affecting the bridge the major causes were reviewed

- Movement of ships and other river craft in the vicinity of the bridge
- Road vehicle movements, particularly the transportation of flammables on the bridge
- The transport of flammable liquids via pipelines located on the bridge, and the management systems in use to maintain the integrity of these.



Based on scenarios defined by MRWA and past reviews, a number of credible scenarios were developed for further investigation. The consequences associated with a variety of vessel collision scenarios were evaluated. Vessels were categorised into six groups representing vessels operating on the river previously and in the future. Sizes range from 40 to 370 tonnes. Details of the vessels can be seen in Table 3.1. Passenger capacities have been directly quoted from operator records.

Table 3.1 Vessel Tonnages Used in Study

Vessel Number	Displacement (t)	Material type	Passenger Capacity
VI	370	Steel	800
V2	270	Aluminium	525
V3	190	Aluminium	450
V4	155	Steel	400
V5	115	Aluminium	284
V6	45	Aluminium	199

For each vessel category the consequences from an impact on the vessels resulting from:

- a 10 knot, head-on collision with the bridge piers or protection for the two design options (navigational spans and dolphin protection and fendering); and
- a 4 knot, glancing collision with the bridge piers or protection for both design options and the non navigational spans.

As a result of the bridge and vessel structural analyses, the impact on the general public will be established.

The frequency at which the identified scenarios occur will be established by determining the number and size of vessels that pass under the bridge. Historical data for Bridge Traffic was obtained from Main Roads WA, while marine vessel data was obtained directly from operators and the Department of Transport. The data will be adjusted to allow for non-alignment of the railway and traffic bridges and the reduced navigational passage resulting from the location of the dolphins.

Jet and pool fire sizes, due to loss of containment of hazardous goods from pipelines, were estimated using mathematical models and heat radiation existing around the fire calculated. Methodology's developed by Shell Research Thornton were used for pool and jet fires respectively.



#### 3.2 Structural Analysis

It has been assumed that if either of the design options were constructed they would be strong enough to take the loads imparted by ship collision. The structural analysis concentrated on the impact that collisions will have on the vessels and the potential for loss of life or injury. This was done by determining the bridge or fendering stiffness and for a particular collision energy, the loads which will need to absorbed by the different vessels.

The structural analysis also undertook the modelling of the non-navigation spans of the bridge in case of collision from a vessel, which has lost steerage or power. It is assumed as per the brief that the vessel is being carried along by the tidal currents at a maximum speed of 4 knots. The structural analysis will concentrate on the collision energy required for span support to be lost and determine the consequences of vessel impacts on Bridge Structure.

#### 3.3 Risk Criteria

The results of the assessment will be compared to the following risk criteria.

#### 3.3.1 Austroads Bridge Design Code Criteria

In section 1 of the design code, limits are set for "serviceability" and "ultimate" loads. The ultimate limit state can lead to a catastrophic failure which could endanger the lives of workman and the public, while the serviceability limit state would occur due to local yielding and deflection of structural elements [2].

The recurrence interval for the serviceability limit state is set at 1 in 20 years and at 1 in 2000 years for the ultimate limit state.

#### 3.3.2 Criteria of the US Department of Transportation

The US Department of transportation set acceptance criteria for the total bridge based upon whether the bridge is regarded as 'critical' or 'regular'. For bridges that are critical to operations, the acceptable annual frequency of collapse must be less than, or equal, to 0.01 in 100 years. For bridges that are considered regular and non critical to operations, the acceptable annual frequency of collapse must be less than, or equal, to 0.1 in 100 years. [1]



#### 3.3.3 Criteria of the Health and Safety Executive (UK)

The Health and Safety Executive (HSE) sets bridge design codes in the UK. They appear in the British Standard BS 5400. This states conservatively that bridge design life should be at least 120 years.

#### 3.3.4 Western Australia Acceptance Criteria

There are no documented acceptance criteria in WA for a construction of this nature.

#### 3.4 Hazard Identification

In previous marine studies the major hazard identified is a head-on vessel collision with an object (eg another vessel, jetty or bridge). However when considering causes of collision by vessels these have been found to be most predominant factors:

- Human error
- Mechanical failure
- Adverse Environmental Conditions

It should be noted that human error and adverse environmental conditions are the main cause of accidents. In terms of the Fremantle Bridge, its location (the position of the sharp dogleg turn to the railway bridge) and climate (winds and tide), human error is potentially the greatest cause of collision. Nearly all skippers talked to during the course of the study supported this.

Design options 1 and 2 both reduce the hazard associated with head on vessel collision in different ways. Option 1 protects the bridge navigation piers by addition of dolphins and strengthened fenders. However the risk of non navigation span collision remains the same. Option 2 provides three new strengthened piers with considerably wider navigation spans. The associated risk of non navigation span collision is reduced due to removal of half the piers in danger. Hazard probabilities are quantified in Appendix 2. Table 5.1 highlights some of the advantages and disadvantages of each design option.

#### 3.4.1 Fire Hazards

Hazard identification for fire scenarios involving hazardous goods was limited to goods transported across the bridge by pipeline. Vehicle accidents involving hazardous goods transportation vehicles were not considered further as the risks associated were negligible when compared to those involving the pipeline.



The pipeline was considered to be at risk from corrosion, erosion, faulty design, impact by object, sabotage and structural failure of bridge. However the largest contributing event to the overall risk for the pipeline is structural failure of bridge from vessel collision. Failure of the structure will lead to pipeline rupture with potential of a pool and/or jet fire impinging on the bridge, bridge traffic and river traffic.

#### 3.4.2 Utility Descriptions on the Bridge

A number of utility services (other than vehicular and pedestrian traffic) utilise the bridge structure to cross the Swan River. These are as follows;

## Natural Gas Pipeline

An 8" steel pressure pipeline carrying gas runs alongside the downstream side of the bridge and is operated by Alinta gas. Manual isolation valves exist on both sides of the river and an expansion joint is fitted approximately halfway across the bridge.

In the event of a pipeline rupture, it is estimated that it may take up to 2 hours to isolate the line after detection.

#### Liquid Hydrocarbon Lines

BP oil operate 4 lines across the bridge, one 8" and two 12" lines carrying heavy fuel oil to East Fremantle refinery. The pipelines are used to fuel ships and there is no alternative form of supply. The oil is pumped across at high pressure (850 kPa). They also operate a 6" pipeline carrying white oil (kerosene, processed hydrocarbon product). All pipelines are located on the downstream side of the bridge.

#### Electrical

Western Power have a 66KV oil filled line and 2 pilots on the upstream side of the bridge.

#### Other Services

Water Corporation operates a 24" watermain on the upstream side of the bridge, while Telstra have cables on the downstream side of the bridge, which must not be interrupted.



## 3.4.3 Bridge Structure

The Fremantle Bridge was constructed in 1938 of timber in 6m spans with the exception of three navigation spans, which are steel beams with timber decks. Proposed design option drawings can be seen in Appendix 1.

Major maintenance and strengthening work has been carried out in the last few decades as listed below:

- 1970's: reinforced concrete overlay placed on deck
- 1976/77: strengthening of navigation span pier fendering systems by driving new and replacement piles, casting concrete nosings and stiffening with a horizontal steel truss.
- 1980: further strengthening of fender systems and a fail safe structure and tie system installed at the navigation span piers
- 1990's: all piles to the approach spans checked and repaired where necessary; timber half caps at the piers replaced by steel beams

#### 3.4.4 Vessel Speed Distribution

The consequence modelling for collisions has been conducted for two speeds for both design options as specified by Main Roads WA. These are as follows:

- 4 knots, approximating the current speed under the bridge; and
- 10 knots, the estimated maximum speed a vessel, under normal operation would travel under the bridge

The consequences of the analyses can be seen in the event trees in Appendix 2.



# 3.5 Frequency Analysis

#### 3.5.1 Vessels operating on the Swan River

The analysis was conducted over 6 vessel sizes ranging from 40 to 370 tonnes. Frequency data for all vessels using the Fremantle Traffic Bridge was obtained from operating periods over the last 10 years. Marine vessel operators on the Swan River were contacted for details regarding timetabled journeys and charters through the bridge per annum. Vessels were placed according to size in each of the six categories. The journeys were split into upstream and downstream as the approach to each differs. Table 3.2 shows sizes of vessels analysed and the current number of scheduled passes through the bridge for each vessel size on the river.

**Table 3.2 Vessel Frequencies** 

Vessei No.	Displacement (t)	Material type	Total no, of journeys ( up & downstream) per annum	Vessel Frequency for single passage of bridge
V1	370	Steel	884	2.26 x 10 <sup>-3</sup>
V2	270	Aluminium	780	2.56 x 10 <sup>-3</sup>
V3	190	Aluminium	780	2.56 x 10 <sup>-3</sup>
V4	155	Steel	780	1.28 x 10 <sup>-3</sup>
V5	115	Aluminium	3472	1.28 x 10 <sup>-3</sup>
V6	45	Aluminium	9680	7.40 x 10 <sup>-4</sup>

#### Note

- no data was available for vessel number 3; the same frequency as vessel 2 has been taken instead.
- the Rottnest Explorer (V1), the biggest boat that has operated on the Swan River has been sold to an operator in Sydney. There is an option to buy the vessel back, but Boat Torque currently have no plans on re-purchasing the boat.



The maximum number of passengers per vessel in each category is shown with approximate capacities given by experienced boat operators. These can be seen in Table 3.3. The vessel data is assumed to include passenger and crew and the percentage full is an average distributed over the year.

**Table 3.3 Vessel Operating Capacities** 

Vessel Number	Max Capacity	Average Occupancy	% Full
Vl	800	320	40
V2	525	210	40
<b>V</b> 3	450	210	50
V4	400	200	50
V5	284	142	50
V6	199	120	60

The frequency of striking navigation and non navigation spans is analysed in the event trees. Detailed calculations are detailed in Appendix 2.

#### 3.5.2 Vehicle Movements across the Bridge

MRWA statistics for 1997/8 indicates that daily traffic flow across the bridge in either direction is 30,100 vehicles per day. For conservatism it has been assumed that all traffic occurs between 6am and 12pm, a similar operating time to the vessels. The average traffic flow is therefore 1672 vehicles per hour. The average speed on the bridge is assumed to be 50km/hr allowing for intermittent flow caused by traffic lights.

It is recognised that during peak hours there will be more vehicles on the traffic bridge, however this only occurs in the morning between 7 and 9 and in the afternoon between 4 and 6. It is also recognised that vessels passing under the bridge at peak times will be small as the majority of timetables inadvertently avoid peak traffic. It is therefore assumed that taking the average traffic flow over an 18 hour period during one day is conservative.

Assessing the value of 1672 vehicles per hour and a travelling speed of 50 km/hr, average traffic density on the bridge was calculated as follows:

Traffic density = Vehicle Rate / Vehicle Speed

= 1672 / 50

= 33 vehicles / km

= 0.033 vehicles / m



This traffic density equates to:

Bridge length 223m, No. of lanes 4
Total length of road on bridge available for cars = 892m

Total length of road available x vehicles per m = 30 vehicles on bridge at any one time

Therefore traffic density equates to over 7 vehicles per lane and 4 vehicles every 30m.

#### 3.6 Consequence Analysis

#### 3.6.1 Fire Hazards

Fire hazards involved on the bridge involve either a jet fire or a flash fire from a natural gas release or a pool fire from liquid hydrocarbon release. The models used in this analysis are the Shell Research Centre for pool fires and the Thornton Research Centre for jet fires [3,4,5,9].

#### Jet Fires

Jet fires result from ignited continuous releases of pressurised flammable gas or liquid. The momentum of the release carries the material forwards in a long plume entraining air to give a flammable mixture. Jet fires have a high flame temperature and can produce very high intensity thermal radiation. The high temperatures pose a hazard not only from direct effects of heat on human beings, but also from the possibility of event escalation. That is, if a jet flame impinges upon a target such as a structural member, it can cause the target to fail. The main aim in modelling the effects of jet fires is to predict the flame length and heat flux. The jet fire model is represented as a frustrum cone, radiating as a solid body with surface emissive power.

#### **Pool Fires**

In the event of a liquid release, immediate or delayed ignition can result in the subsequent development of a pool fire on the surface of an impacted area. As a result of the ignition process, pool fires are often preceded by a flash fire as light components evaporate from the release prior to ignition. Because they are less well aerated than jet fires, pool fires tend to have lower flame temperatures and produce lower levels of thermal radiation than jet fires. However, this means that they will tend to generate more smoke, which can have serious consequences on visibility and air quality. Although a pool fire can lead to structural failure of items within the flame, this will usually take a lot longer than a jet fire. An additional hazard of pool fires is their ability to move with currents. The pool fire model applied in predicting the heat radiation field around a pool fire represents the flame as a cylinder, radiating as a solid body with uniform surface emissive power.



#### Jet Fire Modelling

The natural gas pipeline located on the downstream side of the bridge is the only jet fire source. The following were used as criteria in the jet fire radiation modelling

- Release rates were estimated using the methodology developed by Shell Research Thornton [3,4,5,9]
- A heat flux model of 13 kW/m<sup>2</sup> provides a 30 percent chance of fatality for long exposures, and a very high chance of injury [6].
- Flame dimensions, surface emissive power, and distance from the release point to the 13 kW/m² heat flux level were estimated throughout the model.
- The jet fire results are based on an initial continuous release and the effects of depressurisation of the line have been ignored.

The results of the analysis can be seen in Table 3.4

Table 3.4 Table to Show Effects of Jet Fire Depending on Release Size

Hole Size / mm	Release Rate kg/s	Wind Speed / m/s	Flame Length / m	Max Radiation Level kW/m2	Tolerance time for normally dressed person / s (equivalent to 4.7 KW/m2)
50	1.2	3	10.6	3	7101
		6	9	4.2	638
		10	8.7	6.3	61
100	4.8	3	19.6	4.4	41
		6	16.7	6,8	38
		10	16	8.8	7
Full bore	19.1	3	36.1	5.4	122
		6	30,8	9	6
Transport of the Control of the Cont		10	29	11.8	<5



#### Pool Fire Modelling

The white oil line, transporting processed products such as kerosene and motor spirits, presents the only risk from pool fires. The pipeline operates at 850kPa and can be isolated in approximately 5 minutes once a leak is detected. In the event of a pipe rupture a release on the sea surface will occur. A worst case scenario has been developed using kerosene as the released hydrocarbon. A thirty metre pool diameter has been assumed taking into account hydrocarbon film spreading characteristics on the water surface and tidal movements. The following assumptions have been made:

- The vessel is assumed to be downwind of the fire
- The vessel is 20m from the edge of the fire travelling downstream
- The vessel is in the flame 5m from the edge of the fire travelling downstream

The following radiation level is achieved shown in Table 3.5

Table 3.5 Table to Show Effects of Pool Fire

Parameter	Downstream Value	Upstream Value
Pool fire diameter /m	30	30
Flame Height /m	36.2	36.2
Wind Speed / m/s	10	10
Radiation level at this distance KW/m2	21.3	26
Distance from edge of pool /m	15	5
Tolerance time for normally dressed person / s (equivalent to 4.7 KW/m2)	<5	<5

#### 3.6.2 Effect of Fire and heat radiation on the Structural Integrity of the bridge

The effect of fire heat radiation on the structural integrity of the bridge was conducted in a previous study [1]. Based on the jet fire modelling in Table 3.4 and previous studies it is recognised that exposure to fire as described will not lead to collapse of the Bridge.



#### 3.6.3 Fatality Rates for Jet and Pool Fires

## On the Bridge

It has been assumed that a collision with a navigation span in either design options does not lead to loss of bridge. However collision with a non navigation span can lead to failure of sections of the bridge (as shown in Section 3.6.4). If the deck collapses from an upstream or downstream collision it has been assumed that the bridge deck will collapse. The following case applies on road collapse from vessel collision with non navigation span:

• Road collapse due to impact from vessel on non navigation span leading to deck collapse and pipeline rupture. Due to protection offered from heat radiation from motor vehicles and the speed they cross the bridge, only occupants of 4 motor vehicles caught in the jet fire flame envelope are considered at risk and a further 4 vehicles on the downstream side may collide or driveoff the severed deck. All jet fires across the bridge are considered to be horizontal and perpendicular to the direction of traffic flow. Pool fire radiation will not affect the vehicle occupants directly, however smoke caused by the fire will reduce visibility on the bridge increasing the frequency of collision.

It is assumed there are two occupants on average in the motor vehicle, and for all occupants at risk there is a 100% fatality rate.

#### On the boat

The level of thermal radiation emitted by the pool fire in upstream and downstream cases is very similar. Vessels probable positioning after a collision with the non navigation spans exposes passengers to thermal radiation levels close to  $23 \text{KW/m}^2$  (100% chance of fatality for long exposure and 10% chance of fatality for instantaneous exposure) [6]. Jet fires aimed directly at the vessel would also have the potential to cause large numbers of fatalities.

Due to the protection offered by the boat shell, boat positioning and direction of jet fire a conservative fatality rate of 0.25 and 0.5 for upstream downstream vessels respectively has been used for pipeline rupture. The reason for the difference is due to vessel location, on the upstream side the bridge structure is between the jet and the vessel offering protection, on the downstream side the vessel is directly exposed.



## 3.6.4 Fatality Rate for Structural Collision

There are two types of collisions studied in this analysis, head on and glancing collision. In the event tree analysis glancing has been further classified into nudge and minor glance for fender damage purposes only.

#### Glancing

From reviews of previous studies [1] and discussions with boat operators glancing occurs only on passage through the bridge with many passengers not even realising it has occurred. Therefore the fatality rate associated with glancing is assumed to be 0.

#### Head on

The structure was modelled by considering one pile group of the bridge and assuming a direct hit by the vessel. The members spanning between pile groups are effectively simply supported and therefore do not have a significant capacity to transfer a collision load to adjacent bents, a small contribution only was assumed for the bearers and deck structure. The models were prepared using the software package 'SPACEGASS'. Similar assumptions were made with respect to material properties and member sizes as made in the original study [1], namely:

- Piles 500mm jarrah
- Pile fixity 5 pile diameter below top of soil level
- Timber section stress grade F17
- Ultimate stress levels have been based on AS1720.1-1997

The timber bearers and bracing members have been assumed to be as shown on the drawings. The double channel steel crossbeams have been assumed to be standard 380 PFC's.

In accordance with the brief vessels have been classified in groups 1 to 6 and have been considered to approach the non navigation pile groups at a speed of 4 knots. It should be noted that vessel sizes 1 and 4 were assumed to be constructed of steel whilst the remaining vessel sizes were assumed to be constructed of aluminium.

#### Non Navigation Span Collision

The forces applied to the structure have been calculated iteratively by considering the vessel approach energy, the energy loss in failure or displacement of the bridge structure and the energy loss in crushing of the vessel. It has been assumed that as the vessel breaks through the first row of piles, it is prevented from rolling by adjacent bridge members and thus energy is only lost by deformation of the vessel and bridge. The amount of energy absorbed by the vessel is dependent on its crushing characteristics.



There are no definitive methods for calculating these values, similar techniques to those used in the previous study [1] have been adopted. That is the assumption of an estimated crushing distance of 150mm for a head-on collision of a vessel constructed of steel having a displacement tonnage of 70 tonnes and travelling at 8 knots. This relationship provided a basis for calculating the crushing distances for all vessels included in this study. The resulting calculated crushing distances are shown in table 3.6

Table 3.6 Vessel Crushing Distances

Vessel	Mass	Crushing Distance	Construction
V1	(370t)	240mm	Steel
V2	(270t)	690mm	Aluminium
V3	(190t)	580mm	Aluminium
V4	(155t)	160mm	Steel
V5	(115t)	450mm	Aluminium
V6	(45t)	280mm	Aluminium

It has been assumed that these estimates of crushing distance are maximum values and that where a vessel strikes a structure, which is "soft" or yielding, then the crushing damage is reduced. In order to be able to assign a magnitude to the crushing distance for such events, the following assumptions have been made:

- Crushing distance is proportional to force
- Force that results in maximum crushing is proportional to  $\sqrt{MV}$ .

The methodology used to determine the amount of damage caused to the bridge structure was as follows:

- Load to cause failure of 1<sup>st</sup> pile determined from SPACEGASS
- Calculate energy loss due to ship crushing and deflection of the structure
- Repeat process for the next pile, etc, until vessel energy is absorbed and the vessel comes to rest

Figure 3.1 and 3.2 show the models used in the analysis. These provide a representation of the vessel impact points and the structures deformed geometry after the collision.

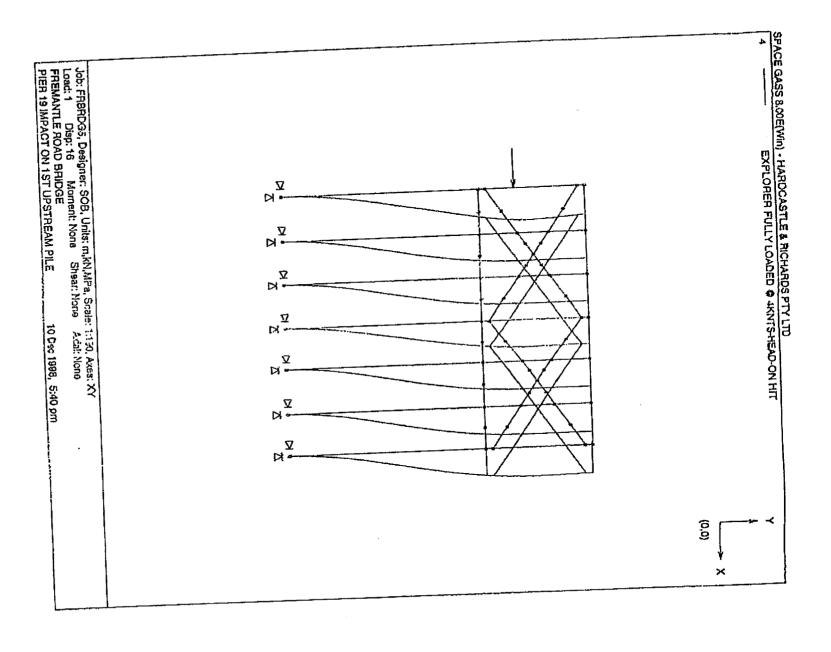


Figure 3.1 Vessel Size 1 Striking the Non Navigation Span First Pile

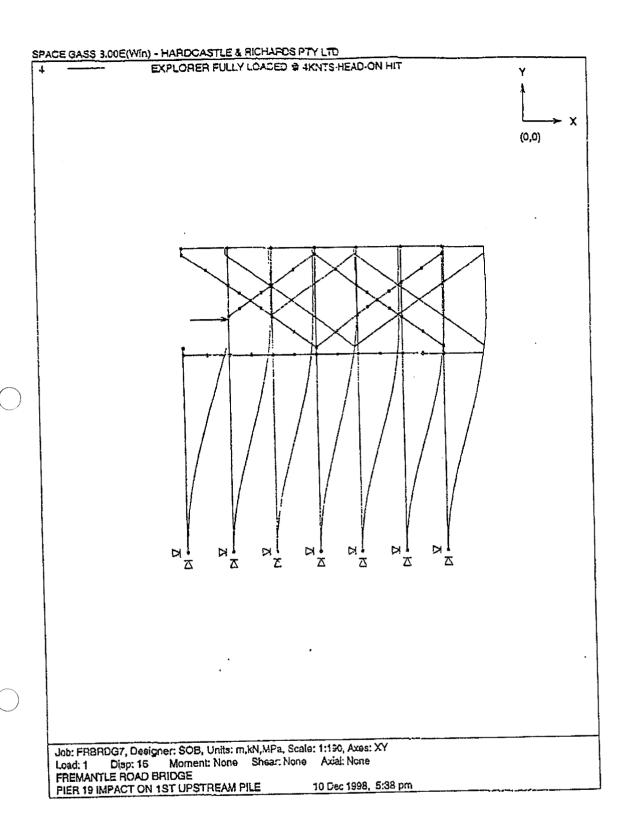


Figure 3.2 Vessel Size 1 Striking the Non Navigation Span Second Pile



Analysis of the structure shows that the first pile fails in bending close to the point of ship impact. Failure of this pile is unlikely to cause collapse of the superstructure, as there is some capacity of the deck to act as a cantilever, and there is some support from the remaining timber framing.

Failure of the second pile, however, is likely to result in the collapse of the whole bridge. The stiffness of the superstructure above the second pile means that high moment loads are transferred to the base of the piles near the mud line. The model shows that under this condition the moment in the remaining six piles in the group is roughly equivalent. This means that when the applied load is sufficient to fail the second pile it is sufficient to fail all the remaining piles. We would expect that under such conditions the bridge would fail progressively.

Analysis shows that vessels 1-4 would cause catastrophic failure of the bridge under a 4 knot head on collision.

Navigation Span Collision

Main Roads have instructed Qest and Hardcastle & Richards that the navigation spans in design options 1 and 2 would be designed to withstand a collision by any of the vessels under consideration without significant damage to the structure. A head on collision provides hazards, which could be fatal. The major fatality contributors are deceleration and sinking.

#### Deceleration

Main Roads have undertaken preliminary designs of the two options including simple mathematical models of the piles structure. The results from these provide a measure of the stiffness of the structure. This in turn allows an estimate to be made of the deceleration, which might be expected under collision conditions. The calculations have been made on the assumption that the vessel strikes the bridge and comes to rest. There would obviously be a number of cases where vessels would strike glancing blows and then veer away, under such conditions the deceleration would be significantly less.



Hardcastle & Richards produced detailed models calculating the ultimate deceleration for both design options for each of the vessels considered. The decelerations are shown in Table 3.7 and 3.8

Table 3.7 Deceleration for Vessels with Design Option 1

	Head on Collisio	n 4 knots (2m/s)	Head on Collision 10 knots (5m/s)		
Vessel	Initial Energy (kNm)	Deceleration (m/s²)	Initial Energy (kNm)	Deceleration (m/s²)	
V1	615	4.9	3840	19.3	
V2	450	2.2	2800	8.7	
V3	315	2.6	1970	10.4	
V4	260	7.5	1600	29.5	
V5	190	3.4	1200	13.5	
V6	75	5.4	465	21.3	

Table 3.8 Deceleration for Vessels with Design Option 2

Head on Collision 4 knots (2m/s)			Head on Collision 10 knots (5m/s)		
Vessel	Initial Energy (kNm)	Deceleration (m/s²)	Initial Energy (kNm)	Deceleration (m/s²)	
V1	615	5.6	3840	22.2	
V2	450	2.2	2800	8.8	
V3	315	2.7	1970	10.6	
V4	260	8.6	1600	33.9	
V5	190	3.4	1200	13.7	
V6	75	5.5	465	21.6	

It can be seen from Tables 3.7 and 3.8 that vessel sizes 1 and 4 have considerably larger decelerations than the others. This is due to the vessel being modelled as steel, which has a greater stiffness than Aluminium on impact.



#### Sinking

The vessels analysed in this report are all passenger ferries operating on the Swan and around the harbour. As such the vessels are required to be built to standards as defined by Transport Marine Safety. Each vessel is sub divided below the bulkhead deck into watertight compartments [7]. A typical vessel contains 6 bulkheads and a collision bulkhead. Commercial vessels are designed that in the unlikely event of a bulkhead loss from a collision, the vessels still remain afloat [8]. In discussions with experienced maritime operators and designers it has been deemed that it would be very unlikely that a head on collision with a navigation span would sink the vessel.

In determining the fatality rate previous studies have assumed a fatality rate of one third of the number of passengers on board [1]. However this study includes the assumption, agreed by Main Roads, that vessels will not sink on impact with the bridge. Assessing the deceleration rates, discussions with experienced mariners and assumed vessel movements on collision the following fatality rates are assumed to be conservative.

A fatality rate of 20% for vessel sizes 2,3,5,6. A fatality rate of 33% for vessel sizes 1 & 4.

A study was carried out to determine the sensitivity of passenger capacities and fatality rates. This can be seen in Section 4.

4.0 FINDINGS





# **FINDINGS**

## 4 Results

The results from the event trees for both Design Options can be seen in Table 4.1 in the format of a FN table.

F: Frequency at which N number of fatalities will occur N: Number of fatalities

Table 4.1 FN Table for Design Options 1 and 2

	Design (	)ption 1		Design (	Iption 2
		Cumulative			Camulative
N	F	Frequency	N	P	Prequency
282	3.0E-9	3.0E-9	282	1.0E-9	1.0E-9
202	3.2E-9	6.2E-9	202	1.1E-9	2.1E-9
174	3.4E-9	9.6E-9	174	1.1E-9	3.2E-9
163	3.4E-9	1.3E-8	163	1.1E-9	4.4E-9
132	8.4E-10	1.4E-8	132	2.8E-10	4.6E-9
117	1.7E-9	1.6E-8	117	5.7E-10	5.2E-9
111	1.7E-9	1.7E-8	111	5.7E-10	5.8E-9
106	1.1E-7	1.3E-7	106	2.0E-8	2.6E-8
66	6.4E-8	1.9E-7	66	1.1E-8	3.7E-8
45	1.3E-7	3.2E-7	45	2.3E-8	5.9E-8
42	1.3E-7	4.5E-7	42	2.3E-8	8.2E-8
28	6.6E-8	5.1E-7	28	1.2E-8	9.4E-8
24	3.8E-8	5.5E-7	24	7.0E-9	1.0E-7



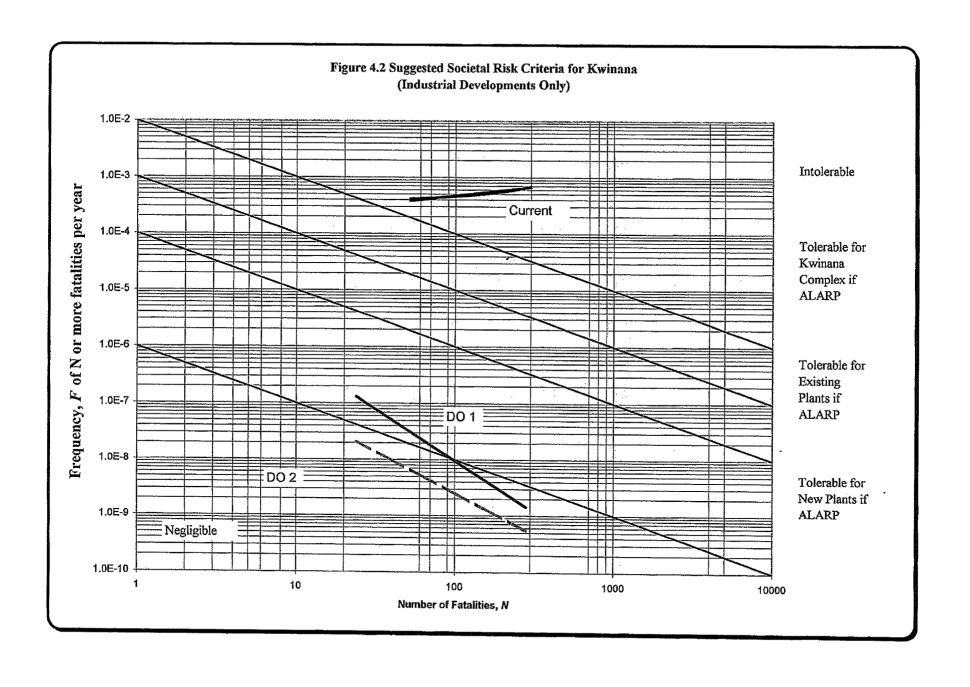
## **FINDINGS**

The cumulative frequency of collisions resulting in a fatality for design option 1 is  $5.5 \times 10^{-7}$  pa and for design option 2 is  $1.0 \times 10^{-7}$  pa. Table 4.2 shows the frequency for the Fremantle Traffic Bridge and compares it with the criteria set out by Austroads and the US Department of Transportation.

Table 4.2 Comparison of Fremantle Traffic Bridge Risk Data with Acceptance Criteria

Body	Criteria	Design Option 1 Acceptable	Design Option 2 Acceptable
Austroads:			
Servicability Load	Minor damage at a rate < 0.05 pa	Ϋ́	Y
Ultimate Load	Bridge collapse at a rate < 0.0005 pa	Y	Y
US Department of Transportation: Critical Loads	Collapse frequency < 0.001 pa	Y	Y
Regular Roads	Collapse frequency < 0.0001 pa	Y	Y

It can be seen from Table 4.2 that both design options meet the acceptance criteria set by both bodies. In terms of Societal Risk Figures 4.1 and 4.2 show the Fremantle Traffic Bridge F-N curve plotted against criteria set out by the HSE and that proposed for Kwinana Industrial Developments. In Figure 4.1 both design option curves can be seen to fall below the negligible risk limit level. In Figure 4.2 design option 1 crosses the tolerable section in the graph, whereas design option 2 is in the negligible risk area again. The criterion compared in Figure 4.2 is the risk for industrial areas and should be stricter for areas of public use such as the Fremantle Traffic Bridge.



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The approximated costs for each design option and its associated cumulative frequency are shown in Table 4.3

Table 4.3 Cost Comparison of Design Options

	Approximate cost/ m5Aus		Factor (fS)
Design Option 1	5	5.5E-7	2.8E-6
Design Option 2	11	1.0E-7	1.1E-6
Difference	6	-4.5E-7	

As Main Roads have no cost benefit criteria, an attempt to represent the relationship between project cost and frequency of fatality has been made by multiplying the approximate cost and frequency. It may generally be considered reasonable that the lower the resultant factor, the better the "safety value" of the design.

It should be noted that even though both design options comply with the specified acceptance criterion, it was found that an increase in the number of glancing collisions per year due to waterway restriction from the dolphins (design option 1) will result. This would also lead to an increase in maintenance. A brief study (Section 4.1) was conducted at Main Roads request.



# 4.1 Collision Frequencies

This study assesses the change in collision frequency from the current navigation spans if any. The probabilities of glancing the bridge were estimated using the same methodology for design option 1 (the methodology can be found in Appendix 2, design option1 nav span collisions). The analysis was repeated using the estimated collision rates for the bridges current status. It should be noted that this is not a risk assessment of the current Fremantle Traffic Bridge, but a separate study conducted using similar design options assumptions on the current bridge set up. Table 4.4 shows the results of the sensitivity analysis.

Table 4.4 Comparison of Glancing Collision Frequencies

Collision Type	Collisi Current	ou Frequ BO 1	RELIEFONDO DO COMO		
Nav glance	1.6E-4	2.7E-4	4.1E-5	72%	-74%
Non nav glance	5.5E-5	5,5E-5	1.8E-5	-1%	-66%
Total glance collisions both span types	2.1E-4	3.2E-4	5.9E-5	53%	-72%

It can be seen from a comparison of collision frequencies that implementing design option 1 increases the amount of navigation span glancing collisions by 72% on the estimated current status. Implementation of design option 2 reduces the number of navigation span glancing collisions by 74%. This increase is heavily supported by anecdotal evidence from experienced skippers operating on the Swan River. Many of the larger boats have less than a metre either side of the vessel as they travel through the bridge. The limited clearance through the Bridge is highlighted by Figures 4.3 and 4.4



Figure 4.3 Boat Torques "Star Flyte" vessel as it traverses the Traffic Bridge from upstream through the wider Northern Span

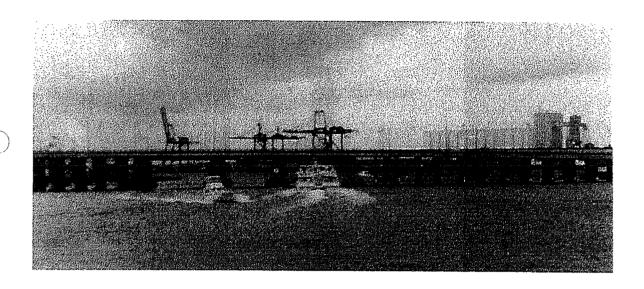
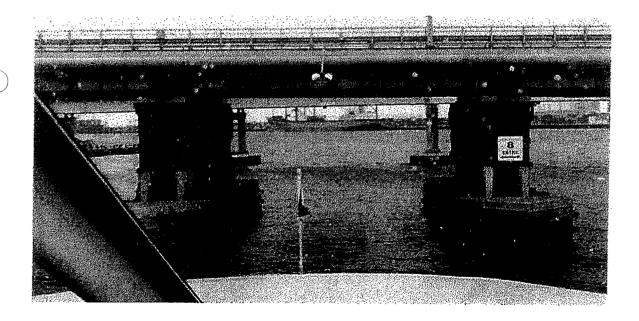
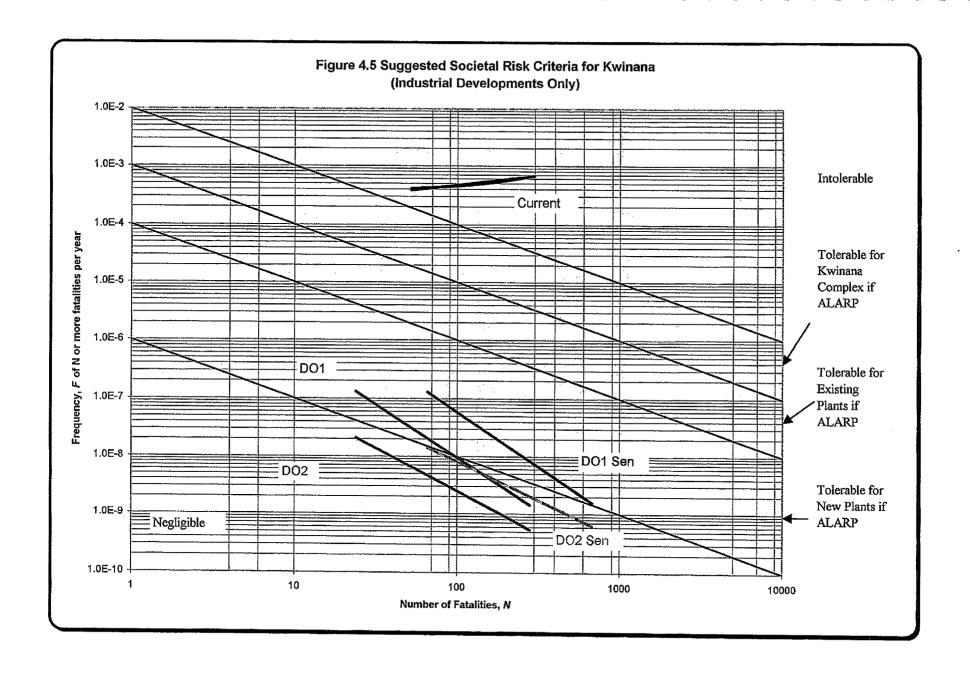


Figure 4.4 Captain Cooks "James Stirling" vessel prior to traversing the Traffic Bridge from upstream through the small Middle Span







# 4.2 Sensitivity - Passenger Fatality Rates

# 4.2.1 Methodology

A sensitivity was carried out to determine the effect of assuming a fatality rate of 20% for specific vessel sizes involved in head on collisions. The Qest event tree model was used in this analysis modifying the maximum number of passengers and assuming a fatality rate of 33% for all vessels on collision. The changes inputted to the trees can be seen in Table 4.5 and event trees and results can be seen in Appendix 3. The sensitivity was conducted for both design options and comparisons made.

**Table 4.5 Sensitivity Modifications** 

Vessel		case Passengers estimated on board	Fatality Rate	tivity Passengers estimated on board
V1	0.33	320	0.33	800
V2	0.2	210	0,33	525
V3	0.2	225	0.33	450
V4	0.33	200	0.33	400
V5	0.2	142	0,33	284
V6	0.2	119	0.33	199

#### 4.2.2 Results

The impact the modifications have on societal risk can be seen in Figure 4.5. The graph shows that for design option 1 the sensitivity FN curve shifts to the right and is almost completely in the tolerable section. Design option 2 sensitivity shifts the FN curve to the right but still remains in the negligible region. All curves are still well below the intolerable level.



# 5.0 CONCLUSIONS



# RECOMENDATIONS

#### **5** Conclusions

- Both design options conform to the accepted criteria set by Austroads and the US Department of Transportation.
- Design option 1 the addition of dolphins to the piers will increase the likelihood of collision as a result of movement restrictions during passage, especially on entry and exit. The narrow middle span, with maximum clearance and favoured by most skippers due to varying tidal heights, will become more hazardous as the manoeuvring distance between the Traffic and Railway bridges is reduced.
- The overall cumulative frequency of collision resulting in a fatality for design option 1 is 5.5 x 10<sup>-7</sup> pa and for design option 2 is 1.0 x 10<sup>-7</sup> pa.
- The current cumulative frequency of glancing collisions with the navigational spans is 1.6 x 10<sup>-4</sup> pa. The overall cumulative frequency of a glancing collision DO 1 is 2.7 x 10<sup>-4</sup> pa, an increase of 72% and for DO 2 is 4.1 x 10<sup>-5</sup> pa, a reduction of 74%.
- From structural analyses vessel sizes of greater than 155 tonnes will cause structural failure of the bridge on collision with the **non navigation spans** at 4 knots or greater.
- From structural analyses vessel sizes of greater than 45 tonnes will cause structural failure of the bridge on collision with the **non navigation spans** at 10 knots or greater.
- The risks to the public resulting from design option 1 are tolerable / negligible when compared to risk criteria for industrial sites (Figure 1.1). Risk criterion for public areas may generally be considered stricter than those presented for industrial developments.
- The risks to the public resulting from design option 2 are negligible when compared to risk criteria used for industrial sites (Figure 1.1). Risk criterion for public areas may generally be considered stricter than those presented for industrial developments.

Table 5.1 shows risk related advantages and disadvantages of both design options.



# RECOMENDATIONS

Table 5.1 Risk Related Advantages and Disadvantages of Design Options

Task		Design Option 1	Design Option 2
Approach	+ ve	Dolphins and fender strengthening  Protect timber structure from possible	Widening the Navigation span
to the bridge	1 46	vessel collision Control the tidal flows through the bridge better.	Presents a less hazardous approach to and through the bridge, as the spans are 34.75m wide. Approx 3 times the width of the widest boat.
			The jetty on approach from downstream will not cause unnecessary manoeuvring of vessels due to better bridge alignment.
From up/down river	- ve	Placement of the jetty on approach from downstream causes unnecessary manoeuvring of vessels as they require approx. 100 metres of approach way.	None identified
Lining up with the bridge	+ ve	None identified	Due to the extra width, winds and currents moving the boat will not force skippers into sudden movements.
	-ve	The piers are extended by an additional 5.5m on each side of the bridge, highlighting the fact of maintaining a good line for safe passage.  Vessels stopping at the East Street Jetty prior to the bridge, will need to make more movements to navigate the bridge after setting passengers down.	None identified
Travelling through the bridge, (currents, wind)	+ ve	The fenders are strengthened to protect the structure from collisions.	Structure is protected from collision The boats have a greater amount of width clearance through the bridges, thus reducing fender damage and chance of structure collision.
	- ve	The length of piers are increased in some case by an additional 11m. This will lead to regular glancing of fenders and increased maintenance costs.  There is a greater possibility of causing damage to vessels on the River.	Currently skippers navigate through the middle span during high tides. The removal of this guide will result in the need to be more aware of tide levels when navigating the Bridge.
Alignment on exit	+ ve	Structure is protected from collision	Structure is protected from collision A line can be taken to avoid sharp turns during bridge passage. The wider span allows a less hazardous line to be taken on passage through both the Traffic and Railway Bridge.
	- ve	From upstream passages the dog leg turn on the middle span is expected to significantly impair vessels navigating both bridges.  A considerable increase in bridge collision is expected to occur due to the reduced distance, tidal currents and wind conditions the vessels must navigate caused by the addition of dolphins.	None identified



6.0 RECOMMENDATIONS



# RECOMENDATIONS

# 6 Risk Mitigation Measures

During the course of the risk assessment, vessel operators and Port Authority personnel were contacted for information. In discussions about the Fremantle Bridge, various suggestions were volunteered on how the bridge could be made inherently safer.

The suggestions are as follows:

Addition of markers hanging from span entrance and exit to allow skippers to line up vessels properly.

Addition of tide height markers on the bridges prior to the Fremantle Traffic Bridge. This allows skippers to get an accurate hold of current tide heights rather than rely on Fremantle Port Authority.

It was highlighted by various skippers that a significant number of private boat owners did not understand the rules of navigation, often causing frustration and extra hazards for other boat users. Perhaps a greater navigation awareness campaign could benefit all Swan River users.

In order to reduce damage to boats and fendering, the addition of impact absorbing fenders was suggested.

Addition of guiding piles to ensure vessels do not ever hit non navigation spans, and also guide vessels though the navigation channels.

Ensure alignment of the Traffic and Railway Bridge if design option 2 is implemented.



7.0 REFERENCES



# REFERENCES

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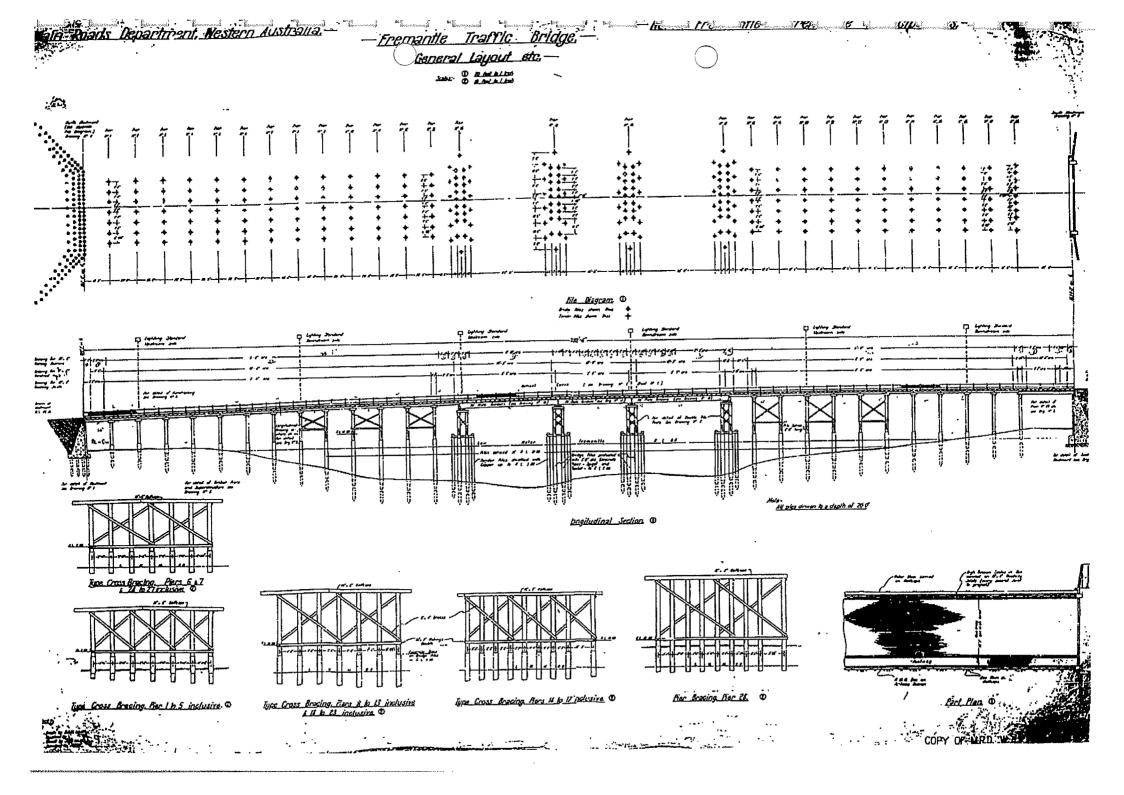


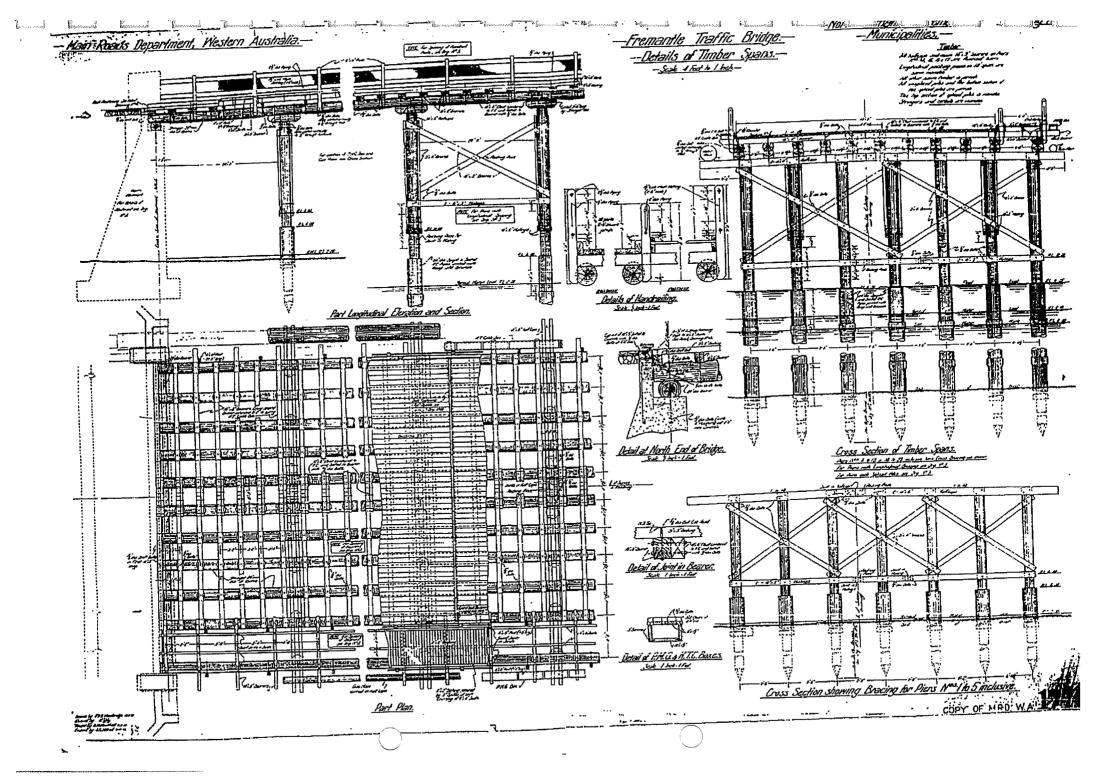
8.0 APPENDICES

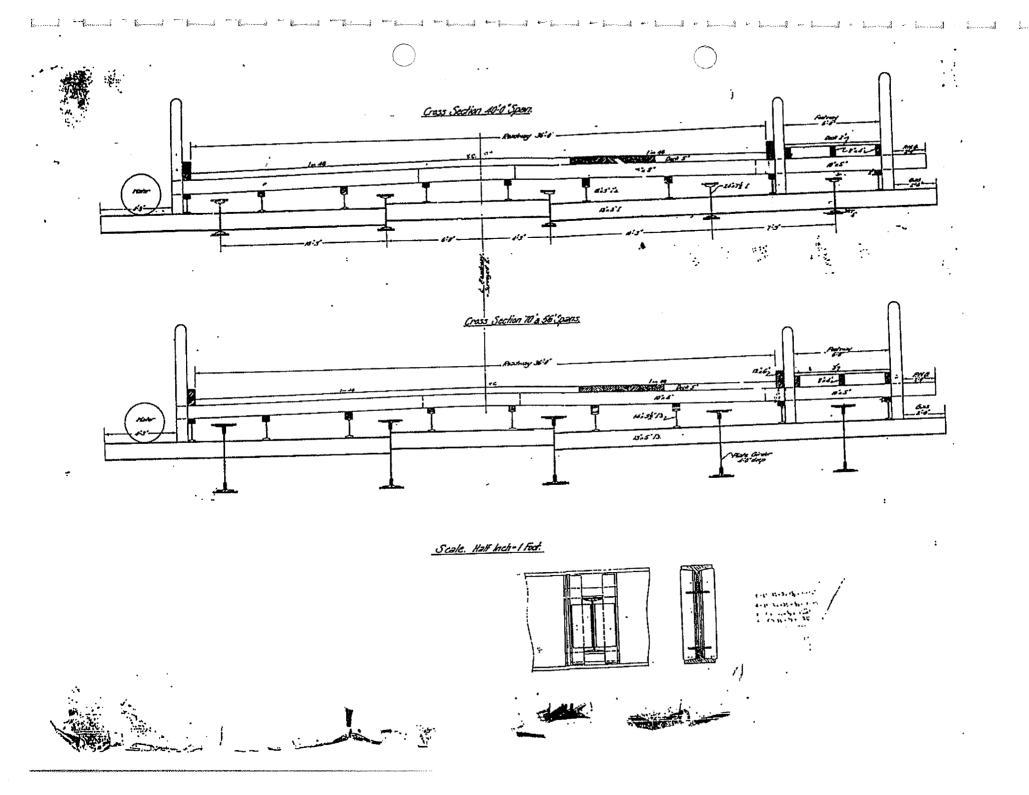


# Appendix 1

General Arrangement Drawings of Design Options

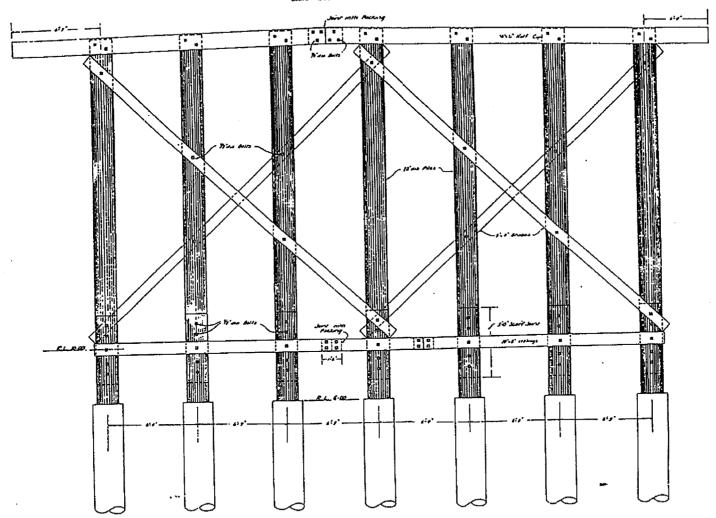




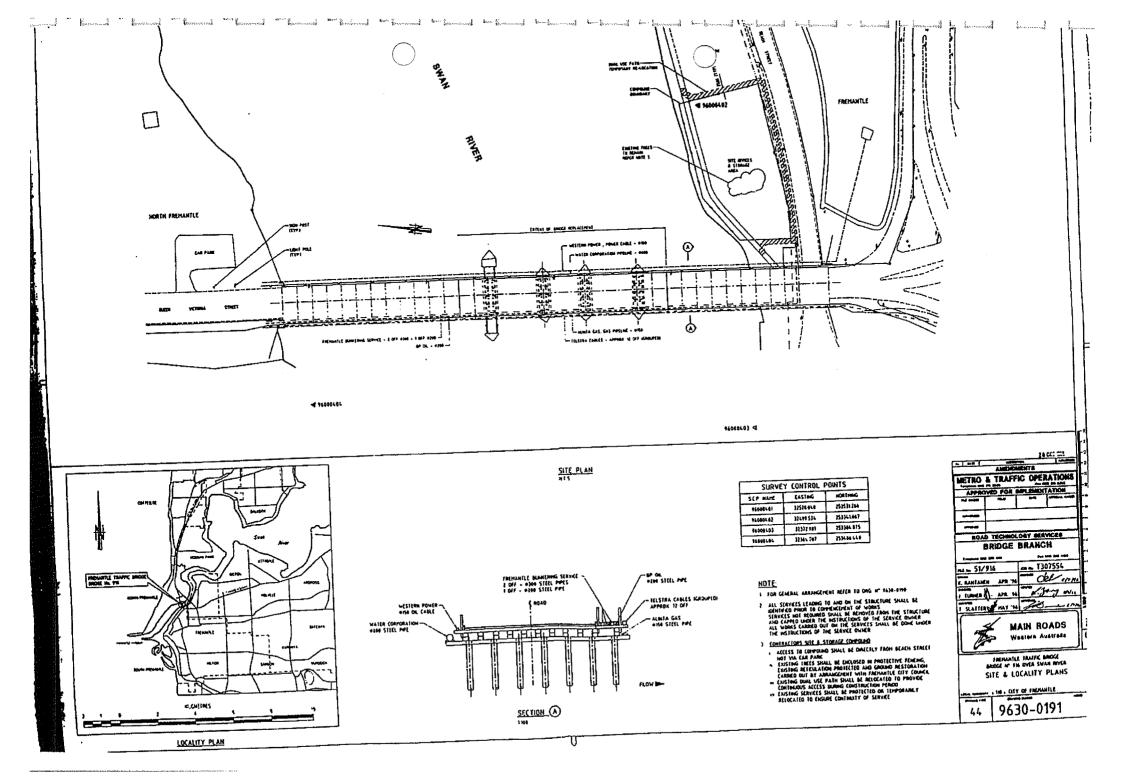


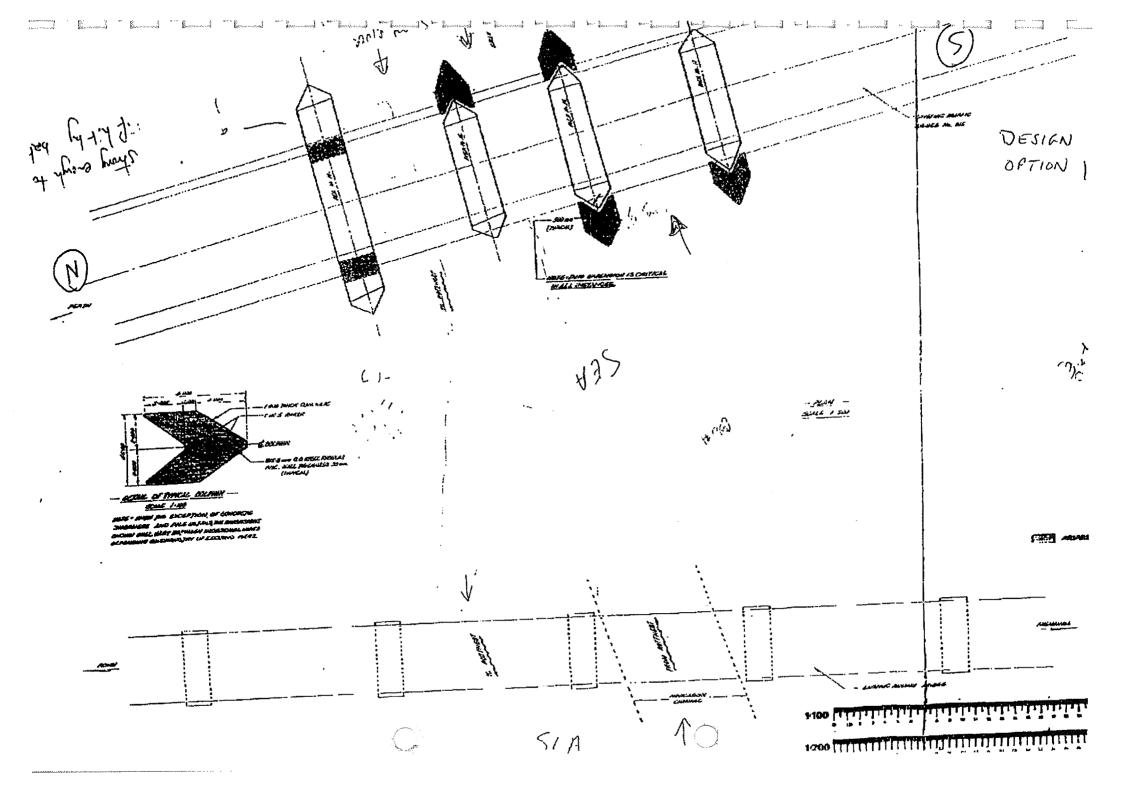
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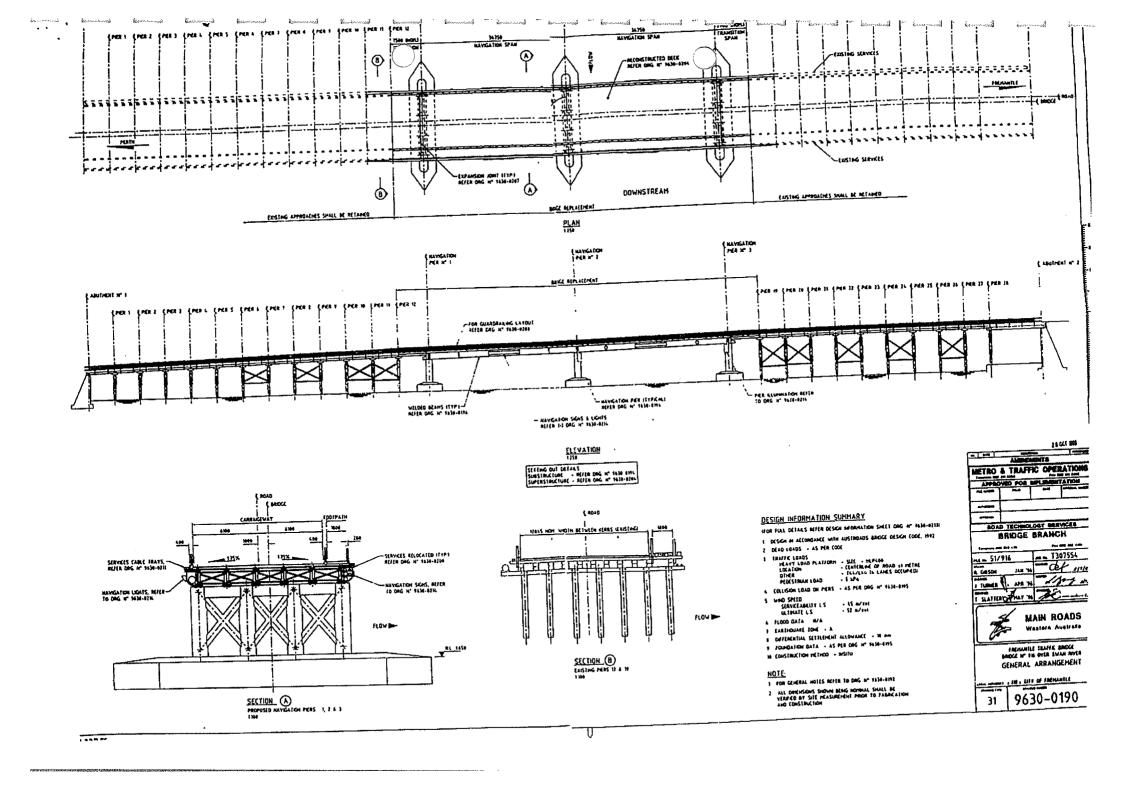
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# Appendix 2

Event Trees for Design Options 1 and 2



# Event tree analysis

#### Nomenclature

The trees are split into different scenarios by vessel size, design option and wether the vessel is travelling from upstream or downstream direction. The nomenclature used to describe the trees is as follows:

Tree V1 DO1 UP Vessel size 1, Design Option 1, Upstream of Bridge Tree V1 DO1 D Vessel size 1, Design Option 1, Downstream of Bridge Tree V1 DO2 UP Vessel size 1, Design Option 2, Upstream of Bridge Tree V1 DO2 D Vessel size 1, Design Option 2, Downstream of Bridge

# Through to

Tree V6 DO1 UP Vessel size 6, Design Option 1, Upstream of Bridge Tree V6 DO1 D Vessel size 6, Design Option 1, Downstream of Bridge Tree V6 DO2 UP Vessel size 6, Design Option 2, Upstream of Bridge Tree V6 DO2 D Vessel size 6, Design Option 2, Downstream of Bridge

The numbers used in the event tree are explained in detail below

# **Design Option 1**

The following are detailed explanations of all figures used in the event tree analysis.

#### 2 Nav span collision

The Bridge was built in 1938, however there are no documented records detailing river traffic for the whole period. There are no documented reports of collisions with vessels on the navigational spans crossing the river. Hence it is difficult to quantify accurately.

However according to anecdotal evidence given by the vessel skippers, vessels glance fendering on the Fremantle Traffic Bridge frequently. For the current Bridge configuration the frequency of glances given by operators ranged between 1 and 6 glances per year.

As this data is extremely difficult to quantify for all vessels a generic collision rate was assumed based on the worst case value. Of those 6 incidents per year, 4 were minor and 2 were severe glances as the vessels pass through the bridge. It should be noted that a minor glance is defined as clipping the fendering on passage through or exiting from under the bridge by turning before the stern of the boat is clear. A severe glance was described as a nudge on the bridge. Again from anecdotal evidence skippers notice a minor glance whereas the majority of passengers are unaware of contact.



The navigation span that causes most problems is pier 15, the left hand side of the smallest navigation span located in the middle, due to vessels turning sharply to gain alignment with the Railway Bridge.

As a result of this evidence the spans are distributed as follows in Table A2.1

Table A2.1 Distribution of glances per navigation span

Span	Number of Glances	Justification
Southern	I	The easiest approach and passage through the bridge
Middle	3	The smallest span and sharp dog leg turn on exiting the bridge
Northern	2	The span has the lowest clearance and a dog leg turn on exiting the bridge

The implementation of design option 1 increases the average length of a pier by 5.5m per dolphin as shown in Figure 2.2. This additional protection lengthens the restricted distance that boats travel through, ultimately leading to an increased number of collisions.

Span	Increased Length	Increased no. of collisions / year	New Total /year
Southern	5.5m a dolphin on either entrance pier	Current pier length = 1 lm (inc current fendering) Increased length = 5.5m No. of extra glances 5.5/11 = 50% % x current glances; 0.50 x I = 0.5	1.5
Middle	11m two dolphins on entrance and one on the pier 15 severely restricting turning	Current pier length = 14m (inc current fendering) Increased length = 11m No. of extra glances 11/14 = 78% % x current glances; 0.78 x 3 = 2.3	5.3
Northern	5.5m a single dolphin on entrance	Current pier length = 16m (inc current fendering) Increased length = 5.5m No. of extra glances 5.5/16 = 34% % x current glances; 0.34 x 2 = 0.68	2.7



A typical vessel passes through the bridge 780 times a year (up and down stream passes based on 14 timetabled trips for the year and 2 charters a week for 26 weeks, denotes summer).

Therefore the upstream frequency of collision is given by

No. of collisions in a year/ No. of passages under bridge in a year

Therefore for vessels travelling from upstream:

(5.3 + 2.7)/390 = 0.021 collisions per vessel per year

and for vessels returning from down stream

1.5/390 = 0.004 collisions per vessel per year

A worst case collision rate was applied to all vessel sizes.

3 Striking the non navigation span

This methodology is valid for upstream and downstream passages. The non navigation spans are located adjacent to the navigation spans exposing 4 piers either side of the outer spans at risk from collision. The remaining piers are located in depths too shallow for all boats at high tide. It is conservatively assumed that there is an equal chance of striking the non navigation spans on up or downstream passages. In the hazard identification study conducted on the bridge, causes of collision with non navigation spans were identified as follows:

- Loss of Steering
- Loss of Power
- Human Error
  - Current variation
  - Wind conditions

#### Steering Failure

Skippers of vessels operating on the Swan River, in the unlikely event of engine failure, are trained to avoid hitting objects such as bridges by using forward and reverse thrusts of the engine or even keep the vessel travelling in circles until help arrives. Vessels passing through the Fremantle Bridge pick their line through the spans 100 metres prior to passing. Loss of steerage prior to this distance would allow the skipper to take emergency action before it was too late.

In discussions with skippers it was discovered that one of them has experienced steering failure 3 times in a 10 year operating period, once on the approach to the bridge. This has been quantified below.



A typical vessel completes river tours or trips to Rottnest twice a day with a couple of extra river charters during the weekend. The average distance is assumed to be 60kms with 16 trips per week.

Therefore the total distance travelled per week is;

 $16 \times 60 = 960 \text{km per week}$  $52 \times 960 = 49,920 \text{km per year}$ 

Using the data provided from the skippers, steering failure is estimated to be 0.3 per year. This gives us a steering failure loss of

 $0.3/49,920,000 = 6.0 \times 10^{-9}$  steering failure per m per year

However for this study we are only concerned with a distance of 100m prior to the bridge, this is the minimum stopping distance needed by large vessels to decelerate and avoid collision with the bridge. Therefore in the approach to the bridge the frequency of steering failure is  $6.0 \times 10^{-7}$ .

# Engine Failure

There are no records of ferries operating on the Swan River having loss of power due to engine failure. Engines in use today are diesel and are required to have regular servicing every 3 to 6 months. A vessel operator stated that it was company policy not to pass through the bridge with a damaged engine if it were to occur. It is a Department of Transport requirement for any vessels with engine failure to set down the passengers at a safe drop of point as soon as possible.

The risk associated with engine failure is deemed negligible compared to the major contributor, human error.

#### Human Error

The major contributor to risk associated with vessel collision, is caused by human error. A review of accident studies on vessel collisions, reports that the single largest contributor to accidents at sea is associated with human factors such as human reaction. In general the human factor accounts for some 40%. The human factor is predominant in situations such as vessel collision, grounding and accidents involving personnel [10].

The majority of vessels operating on the river are made of aluminium and do not sit very deep in the water hence are prone to different wind and tidal conditions constantly effecting manoeuvrability. The human factor takes into account how each skipper deals with the conditions on passing through the bridge. However on the Fremantle Traffic Bridge collisions caused by human error are attributed to be 80%.



Due to the positioning of the non navigation spans it has been assumed that it is only possible for them to be struck on approach to the outer spans. Therefore if we assume the number of collisions with the outer spans, 80% is attributable to human error.

Thus the number of collisions due to human error is  $(2.7 + 1.5) \times 0.8 = 3.4$ . As discussed in 2 navigation span collision; the average number of passes through the bridge is 780 per year. Therefore a probability of  $3.4/780 = 4.3 \times 10^{-3}$  is obtained for collisions deemed to be caused by human error.

The total frequency associated with striking a non navigation span is;

Freq of engine failure + Freq of steerage failure + Freq of human error collision

However there are no records of vessels striking non navigation spans on the Swan River. It will be assumed for conservatism that 60% of all vessels, on loss of power, steerage or human error will strike the non navigation spans. This factor takes into account the depth of the river, tidal conditions, wind conditions and traffic conditions around the bridge.

$$(6.0 \times 10^{-7} + 4.3 \times 10^{-3}) \times 0.6 = 2.6 \times 10^{-3}$$

Note Freq of engine failure is deemed negligible compared to other contributing risk factors.

For conservatism the collision rate has been assumed to stay the same for all vessel sizes.

4 Strikes object at a speed greater than 4 knots

This methodology is valid for upstream and downstream passages. All vessels pass through the bridge at a speed greater than 4 knots. Four knots is assumed as the average current speed on the Swan River. All vessels due to there size and weight must maintain a speed at least 8 knots when passing through the bridge otherwise the vessels lose manoeuvrability. Therefore it has been conservatively assumed that on approach to the bridge 95% of vessels will be travelling above 4 knots per hour. This applies to all vessel sizes.

#### 5 Striking the Bridge

This methodology is valid for upstream and downstream passages. As discussed earlier in 2 striking the nav span, the current worst case of collision was deemed to be 6 times per year. From historical operator data, the bridge has been exposed to river traffic for 95 boat years (The sum of all boat operating histories available).



As discussed in 2 the assumed number of collisions per vessel size is 6 times a year. Of those 6 incidents per year, 4 are minor glances and 2 are severe nudges as the boat passes through the bridge. There are no recorded incidents of a head-on collision in the life of the bridge. However there has been one incident in the port involving a ferry colliding with a steel navigation marker in the port. As a result of the collision extreme damage occurred to one side of the vessel, shattering windows over passengers, no fatalities were recorded. For conservatism this incident will be classed as the only direct collision in the bridges operating period.

If the fenders are accidentally struck 6 times a year then the total number of collisions according to available data is:

Number of incidents per year x boat operating period (years) = Number of incidents overall in operating period

Glancing

 $4 \times 95 = 380$ 

Severe Nudge

 $2 \times 95 = 190$ 

Total

570 Incidents in bridge operating

It has been assumed that there has been one head on collision during the operating period data available. Therefore the type of collision can be calculated as a ratio of all collisions.

Head on

1/571

= 0.0018

Glancing

380/571

= 0.66

Severe Nudge

190/571

= 0.33

For conservatism these values have been applied to all vessel sizes.

#### 6 Structural Failure

According to Main Roads, the navigation spans in design options one and two will not lead to structural failure of the bridge on vessel collision. A failure probability of 0 has been assumed for these spans.

From the detailed structural analyses completed by Hardcastle & Richards on the non navigation spans. Vessel sizes 1 to 4, are assumed on collision with the non navigation spans to cause the bridge to fail. A failure probability of 1 has been assumed for these vessels. Vessel sizes 5 and 6 on collision do not cause structural failure of the bridge and a failure probability of 0 has been assumed for these vessels. These probabilities apply for upstream and downstream events.



# 7 Gas/Oil Pipeline Rupture

Oil and gas pipeline rupture can occur from corrosion, bridge structural failure, sabotage or impingement by an object. Of these causes the largest contributor to risk in the case of the Fremantle Traffic Bridge is bridge structural failure.

The possibility of pipeline rupture from structural failure can only occur in both design options by a head on collision with the non navigation spans. Therefore it is conservatively assumed that on structural failure the pipeline will rupture. A failure probability of 1 has been assumed for structural failure. This is generic in all event trees.

# 8 Ignition Probability

Typical ignition probabilities for hydrocarbon releases on an offshore platform into a working environment are deemed to be 0.1. However during normal operation of a platform there are minimal ignition sources. In the event of a collision leading to pipeline rupture it is recognised that there will be a considerably larger number of ignition sources present such as motor vehicles on the bridge, smoking on the boat, sparks from impact and failing steel supports. Therefore an ignition probability of 0.3 will be used. This is generic in all event trees.

# **Design Option 2**

The difference between design option 1 and 2 event trees is only noticeable in the collision probabilities with the navigation and non navigation spans. Otherwise the event tree probabilities are assumed to be generic.

# 2 Striking the navigation span

In design option 2 the number of navigation spans are reduced from three to two and span distances increased to 34.75m wide an increase of over 20m per span. This increase in span width increases boat width clearance, thus further reducing the possibility of collision. In the bridge's current state and in design option 1 the minimal width clearance for larger vessels is as small as 1m either side of the boat. In design option 2 the clearance is 12.5m clearance either side for the largest boat.

As mentioned in design option 1 each vessel was assumed to glance the bridge 6 times a year during up and downstream passages. The human error factor was assumed to be conservative at 80%. The span width is dramatically increased almost eliminating human error completely, however for conservatism a 5% human error factor will be used.



In design option 1, 80% of the 6 collisions per year are assumed to be from human error.

Therefore  $0.8 \times 6 = 4.8$  collisions per year due to human error.

Leaving 1.2 collisions per year from other external factors

In design option 2 the number of collisions per year due to a human error is deemed to be 5% of the worst case value.

Therefore  $0.05 \times 6 = 0.3$  collisions per year due to human error

Adding the other external factors with the new human error factor we find the total number of glancing collisions per year to be 1.2 + 0.3 = 1.5

Splitting the total number of collisions into upstream and down stream collision we find there are 0.75 collisions per year in up or down stream spans.

Therefore for vessels travelling upstream or downstream:

No. of collisions in a year / No. of passages under bridge in a year

 $(1.5 / 2) / 390 = 1.9 \times 10^{-3}$  collisions per vessel per year

The frequency associated with navigation span collision is  $1.9 \times 10^{-3}$  an order of magnitude lower than the upstream frequency. The collision probabilities are assumed to be the same for all vessel sizes upstream and downstream passages.

#### 3 Striking the non navigation span

In design option 2 to compensate for the increased width of the navigation spans, two non navigation piers either side of the outer spans are removed. Thus reducing the number of spans available for structural failure. The approach to the bridge by vessels will be less hazardous as skippers can align vessels for a less risky passage through both Bridges. In order to compensate for this change in the event tree the probability of collision with a non navigation span is reduced by a factor of 3.

The collision probabilities are assumed to be the same for all vessel sizes upstream and downstream passages.

The state of the s

# Design Option Input Data

Strengthening Nav Spans elongating them by 5.5m Widening of Nav spans DOI DO2

	4-12			V	2 slightly smaller t	ioal								
	V1	370	touries		V2	270	toruics	_	V3	190	tonnes		V4	155
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Uustream	Downstream
Tree Data	I VI DOI UP	VI DOI D	V1 DO2 UP	VI DO2 D	V2 DOI UP	V2 DO1 D	V2 DO2 UP	V2 DO2 5	V3 DOL UP	V3 DO1 D	V3 DO2 UP	V3 DO2 D	V4 DOT UP	V4 DOLD
Frequency	2 2.26E-03	2.26E-03	2.26E-03	2.26E-03	2.56E-03	2.56E-03	2,56E-03	2.56E-03	2:56E-03	2.56E-03	2.56E-03	2.56E-03	1.28E-03	1.28E-03
No. of people exposed on boat	3 320	320	320	320	210	210	210	210	Color 125	225	225	225	200	200
No. of people exposed on bridg	4 16	lo	16	16	lő	16	16	16	16	16	16	lo	16	ló
Strikes Nav Span	5 0.021	0.004	0.0019	0.0019	0.021	0.004	0.0019	0.0019	0.021	0.004	0 0019	0.0019	0 021	0.004
Strikes Non Nav Span	6 0,003	0.003	0.0009	0.0009	0.003	0.003	0.0009	0.0009	0.003	0.003	0.0009	0.0009	0.003	0.003
Strikes at speed greater than 4 k	7 0.95	0.95	0.95	0,95	0.95	0.95	0,95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Strikes at speed greater than 4 k	8 0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Strikes Head on	9 0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	8100 0	0.0018	0.0018
	10 0.33	0.33	0.33	0.33	0.33	0.33	0.33	0,33	0.33	0.33	0.33	0.33	0.33	0.33
Causes Structural failure Non	11 55 7 4 5 5 5	Ĺ	1	1	ı	]	1	1	1		1	1	1	1
	12 0	0	0	0	0	0	0	0	Ö	0	0	0		0
Gas/oil pipeline failure	13 00.005	1	0.5	I	0.5	1	0.5	1	0.5	1	0.5	i	0.5	1
Ignition	14 03	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	03
Bridge fatality rate from pool &	15 1987 (\$1 9 3 6)	1	l l	1	1	1	l I	1	1	1	1	1	1	V3
Hoat fatality rate from jet & po	16 0.25	0.5	0.25	% 03 V	0.25	0.5	0.25	0.5	0.25	0.3	0.25	0.5	0 25	0.5
Hoat fatality rate glancing collis	17	0	0	0	0	0	0	G G	0	<u> </u>		0.3	<u> </u>	0.3
Hoat fistality rate sinking/decele	18 6 0.33	0,33	011	033	0.2	0.2	0.2	07	0.2		0.7	· 67	633	0 11

# Design Option Input Data

								Boats sinaller			
	_	tonnes		V5	115	tonnes		V6	45	tonnes	
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Tree Data	- 1	V4 DO2 UP	V4 DO2 D	VS DOL UP	VS DOLD	V5 DO2 UP	V5 DO2 D	V6 DOI UP	V6 DOI D	V6 DQ2 UP	V6 DO2 D
Frequency	2	1.2813-03	1.280-03	1280-03	1.2818-03	1.286-03	1.286-01	7.4012-04	7.60E-04	2.40K-04	7,401-03
No. of people exposed on boat	_3	200	200	142	142	142	142	119.4	119.4	119.4	119.4
No. of people exposed on bridg	4	lo	16	10	lά	16	16	10	ło	10	16
Strikes Nev Span	5	0.0019	0.0019	0.021	0.004	0.0019	0.0019	0.021	0.004	0 0019	0.0019
Strikes Non Nav Span	6.	0.0009	0.0009	0,003	0,003	0.0009	0,0009	0.003	0.003	0.0009	0 0009
Strikes at speed greater than 4 k	. 7	0,95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Strikes at speed greater than 4 k	- 8	0.95	0.95	0.95	0,95	0.95	0.95	0.95	0.95	0.95	0.95
Strikes Head on	9	0.0018	0.0018	0.0018	0,0018	0.0018	0.0018	0.0018	0.0018	8100.0	0.0018
Glances	10	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Causes Structural failure Non	11	1	1	Q.	0	0	0	0	0	0	0
Causes Structural failure Nav s	12	0	0	0	0	0	0	0	0	0	0
Gas/oil pipeline failure	13	0.5	1	0.5	ı .	0,5	1	0.5	1	0.5	1
Ignition	14	0.3	0.3	0.3	0.3	0,3	0.3	0.3	0.3	0.3	0.3
Bridge fatality rate from pool &		l	1	1	L	1	1	i	1	1	1
Boat fatality rate from jet & po	16		0.	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5
Boat fatality rate glancing collis			0	0	0	. 0	0	0	0	0	0
Boat fatality rate sinking/decele	_18	0.33	0,33	0.2	0.2	0.2	0.2	0.2	0.2	0.7	0.2

.

Remarked Rem

Event tree for passage through Fremantie Bridge

Boat Name : <u>Vessel 1</u>
Code VI DOI UP
Design Option 1 Addition of dolphins and fender strengthening

People exposed on boat

stream of bridge, travelling into the harbour		People exposed o	n bridge	Immediate	People exposed on boat					
ents	Consequen	ces Bridge	Consequences Boot							
1 2 3 4 5 6 7 8 9	10   11   Fal2ay	13 14	En15tru 6	17 18 1	19 20 18	19 20	21 22	23		
Strikes Strikes at speed Nav Non Nav greater than requency Span span 4 knots bridge I falker rupture Ignition Frequency Outcome	Rate from pool and jet fire exposure on bridge	No. of fatakties PLL	Rale from pool and jet fire exposure on boat fatalities		itles PLL Rate	No. of fatafiles PLL	Total No. of fatables Total PLL			
	es (NG or WO) 2 1	16 16	0.25 80	33	0.33	320 106	201.6			
y 0.7 Falaitles from Speed assum	head on collision only id to be >=8 knots head on collision only				0.33	108	105,6			
0.0018   n   Speed якзит   head on   1   8.12E-08   Falailies from	d to be >=8 knots head on collision only b				0.33	108 106 8 58E-08	105.6 105.8 8.58E-06	3 8 12		
9 0.33 1.50E-05 Fatalities from Speed assum 9 0.67 3.00E-05 Fatalities from Speed assum	d to be >=8 knots glancing fenders only d to be >≥0 knots									
O 2 1 481: GU Philaine rigito	d to by 4 hinds se (NO or WO) self pool fire & cometon	ta oote an	0 26 60 0	3 701 07	6 33 0.33	104 ( bn): ()/	J010 4870 ()7	1		
1 n Speed assum y 0.5 4.92E-09 Fatalities from	d to be >=8 knots				0.33	108 5.205-07				
	head on collision only b				0.33	106	105 6			
nudge         Speed assum           0.0026         0.67         3.64E-06         Fatakiles from	d to be >=8 knots									
0.98 0.05 2.88E-07 Speed assum 0.9974 2.21E-03 Boal passes to 2.0974	pimpact onto structure e d to be 4 knois									
0 South pusses \ \ \	suci mage	<del>-</del>				****	Total PLL 9.95E-06			

cool
Natural gas / Oil pipeline
Head on collison > 8 knots
Nudging collision > 8 knots
Glancing collision > 8 knots
Severe glancing impact onto structure. LOP
Straight through

Event tree for passage through Fremantie Bridge

Boat Name: y
Code V1 D01 D
Design Option 1 Vessel 1

Addition of delphins and fender strengthening

People exposed on boat

Downstraan		je, travelli	ng from the h		ento testos:	i >(i a)sRr	i los iks A					People	exposed o	n bridge			Immediale	Maopi	e exposed o	an boat					
Events											Conseque	rces Brida		Conseque	nces Boat										
1	2	3	4	5	8	7	8	9	10	11		13	14	F-15-14	16	17	18	19	20	18	19	20	21	22	23
Frequency	Sirikes Nav Span	Sirikes Non Nav	Sirikes at speed greater than 4 knots	Strikes bridge	Causes Structura	Pipeline	lonition	Frequency	Outcome		Rate from pool and jet fire exposure on bridge	No, of	PLL	Rate from pool and jet fire exposure on boat	No. of	PLL	Boat Collision Glancing Fatality Rate	No. of	PLL	Boat Coxision Head On Fatality Rate	No. of	Pil	Total No.	Total DI I	Freq
	***************************************	A										16	1 100	5,7554.	320		1	320		T Trails	320	, ,,,,		JOHNYCE	7764
						1_	0.3 y		Pipeline ruptures (NG or WO) Falatities from let, ppol fire & collision	a	1	16		0,6	160					0.33	106		281.6		
						у	0.7 n		Fatailles from head on collision only Speed assumed to be >=8 knots	l b										0.33	106		105.6		
			1	0.0018 head on				1 555 00	Fatalties from head on collision only Speed assumed to be >=8 knots	b										0.33	108		105,8		1
			1.0 y	0,33	<u> </u>			L	Fatalities from head on collision only Speed assumed to be >≃8 knots Fatalities from nudging fenders only											0.33	108	1 635-06	105 6	1 63E-06	1.55E+
٦	0.004 y		′	nudge 0.67					Speed assumed to be >=8 knots Fatalities from glancing fenders only	١															
442			0,05	ninor gland	e			4.52E-07	Speed assumed to be >≃8 knots Severe glanding impact onto structure																ļ
			n			اما	0.3	3.01E-09	Speed assumed to be 4 knots Pipeline ruptures (NG or WO)	a	1	16	1.12E-07	0.5	150	1.12E-06				0,33	106	3.17E-07	281.6	1.55E-08	3.01E-
0.0022624					. 1	<u>,</u>	0.7		Fatalities from let pool fire & colision Fatalities from head on collision only	Ь										0.33	106	7.41E-07	105.6	7.41E-07	7.01E-0
f				0.0018	<del>,</del>	<u> </u>			Speed assumed to be >=8 knots Falaities from head on collision only Speed assumed to be >=8 knots	ь										0.33	108		105 8		
			0.95	head on	<u> </u>				Falaities from head on collision only  Speed assumed to be >=8 knots	Ь.										0,33	168		105 0		
			y	0.33 nudge				1.85E-0 <del>8</del>	Fatablies from nudging fenders only Speed assumed to be >=8 knots	]e															
		0.0026 y		0.67 ninor glane	e				Fataiities from glancing (enders only Speed assumed to be >≃8 knots	d															
L	1.00 n	0.9974	0.05 n						Severe glancing impact onto structure Speed assumed to be 4 knots	•															
	L	D.9974_						2.25E-03 2.25E-08	Boal passes under bridge	ľ															
			Outcomes			Che	ck sum	2.26E-03		_										**			Total PLL	3.93E-06	

The second of th

Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots Glancing collision > 8 knots

Severe glancing impact onto structure, LOP Straight through

Proposed Francisco Francis

Event tres for passage through Framentie Bridge

Boat Name: Vessel 1
Code V1 DO2 UP

Design Option 2 Widening of navigation spans

Upstream of bridge, travelling into the harbour

People exposed on boat

People exposed on bridge

Immediate

,,	DIN MAL	na romany	NKO (UO UMD	JUDE								People	exposed o	n bridge			Immediate								
vents											Conseque	nces Bridg		Conseque	nces Boat										
1	2	3	4	5	6	7	8	9	10	11	Falkin	13	14	FalSilv	16	17	18	19	20	18	19	20	21	22	23
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structura	Pipeline		Frequency	Ostroma		Rate from pool and jet fire exposure on bridge	No. of	PLL	Rate from pool and jet fire exposure on boat	No. of	PLL	Boat Collision Glanding Fatality	No. of	PLL	Boat Collision Head On Falality	No. of		Total No		
requester ;	Срип	1 Juni	1 7 11013	I onego	THEORE	Tupiere	I INTRICATE	Trieddelle	TORCOME		I bei unbyo	16	I. FLL	Untugat	320	1 FLL	Raje	fatalities 320	<i> </i>	Rate	fatakties 320	PLL	of falamies	Total PLL	Freq
														1	320			320			320				1
						0.5	D.3		Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collision	]=	1	16		0.25	60					0 33	108		2016		
						y	0,7 n		Falailles from head on collision only Speed assumed to be >=8 knots	þ										0.33	108		105 6		1
				0.0018 head on	, ,	0.5 n		7 255 00	Fataliles from head on collision only Speed assumed to be >= 8 knots Fataliles from head on collision only	ľ										0.33	106		105 8		
			1.0 y	0.33	<u> </u>				Speed assumed to be >=8 knots Fatalities from nudging fenders only	ľ										0 33	106	7 76E-07	105 6	7 76E-07	7 35E-
Г	0.002 y		1	nudge 0.67					Speed assumed to be >=8 knots Fatalities from glancing fenders only	ď													E		
442			0.00	nisto glanc	:•				Spend manuscript to he >= 8 knote ttavara glassolog hupant erdin altretuse																
			16			0.5	-9 <u>3</u> -	5 025 10	Preed assimed to be 4 knots Prostre (mitues (NO in WO) Fatallies from jol pool fire & consion	-	ŀ	1n	1 8/1° 08	4) 70	24)	v 37F 68				0 11	II)a	า พากเก	JB1 0	1 ONF U/	DAME
.0022824					11	ÿ	0.7 n	1.17E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	ŀ										0.33	106	1.246-07	105 6	1.24E-07	1.17E-
				0 0018 head on	y	0.5 n		1.67E-09	Fatalities from head on collision only Speed assumed to be >≈8 knote Fatalities from head on collision only	b										0.33	106	1 77E-07	105.6	1.77E-07	1.67E-
		-	0.95 y	0.33	n			6.19E-07	Speed assumed to be >=8 knots Fatalities from nudging fenders only	l <sub>c</sub>										0.33	106		105 6		
	,	0.0009		nudge 0.67				1.24E-06	Speed assumed to be >=8 knots Falakties from glancing fenders only	đ															
L	1.00	y	0.05	ninor giano	e			9.79E-08	Speed assumed to be >=8 knots Severe glancing impact onto structure	e															
		0 9991 n							Speed assumed to be 4 knols Boat passes under bridge	,															
			Outcomes			Che	ck sum	8.52E-09 2.26E-03		_													Total DLI	1.24E-06	

cool
Natural gas / Oil pipeline
Head on collison > 8 knots
Nudging collision > 8 knots
Glancing collision > 8 knots
Severe glancing impact onto structure, LOP
Straight through

105.6 7,76E-07 7,35E-09 2.47E-07 2.34E-09 5.18E-07 1.00E-09 Free Total Pt.1 201.6 105.8 281.6 105.6 105.6 105.6 105.8 7.76E-07 \$.06E-07 2.47E-07 6 No. of falables 320 108 8 5 5 5 18 Boal Collision Head On Falality Rate Williams of the control of the contr 0.33 0.33 0.33 0.33 0.33 0.33 0.33 033 People exposed on boat No, of fatalities 320 19 Immediate 8 pat Boat Colfision Glancing Fatality Rate 3,756-07 Consequences Boat 3 180 Rate from pool and jet fire exposure on boal 6.5 0.5 People exposed on bridge 3.755-08 Ξ Consequences Bridge 16 9 Rate from pool and jet fre exposure on bridge Ezlân 2.72E-06 Fatalities from glanding fenders only Speed assumed to be 2-8 knots
2.15E-07 Severe glanding fropact only structure 1.10E-07 Severe glanding fropact only structure 1.10E-07 Fatalities from the Leod for VWO Fatalities from the Conference III of VWO Fatalities from the Leod for VWO Fatalit Speed assumed to be >=8 knots
9.79E-08 Severe gamenting inspect onto situature
Speed assumed to be 4 knots
2.28E-03 Boat passes under bridge Speed assumed to be >=8 knots
7.35E-09 Felshifes from head on colision only
Speed assumed to be >=8 knots
1.30E-06 Falshifes from nudging lenders only
Speed assumed to be >=8 knots Speed assumed to be >=8 knots
6.19E.07 Failaities from nudging fenders only
Speed assumed to be >=8 knots
1.24E-06 Failaities from glanding fenders only Causes Gas/Oil
Structura Pipeline
Isalure rupture (goillon Frequency Outcome 0, v 0.7 ^ <u>}</u> Event tree for passage through Fremantle Bridge
Bate Name:
Code
V 1002 D
Middening of navigation spans
Downstream of bridge, traveling from the harbour 0.33 rxdge 0.67 mlnor glance 0.0018 head on nudge 0.67 Sirikes bridge Strikes at speed greater than 4 knots 무~ Strikes Non Nav 0.0009 Strikes Nav Span 8 -Frequency 0.0022624 7

Outcomes Check suni 2.26E.03

Outcomes Ablural gas / Oil pipekine

Total PLL 1,54E-08

a Natural gas / Oit pipeline b Head on collison > 8 troots

c Nudging cotision > 8 knots
Glanding cotision > 8 knots
e Service glanding impact onto structure, LOP
f Straight through

Event tree for passage through Fremantle Bridge

Boat Name: <u>Vessel 2</u>
Code V2 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening

People exposed on boat

Upstream o	f bridge,	travelling	into the har	pont	w,u .u.u	,, -,,,						Peopl	e exposed o	n bridge			Immediate	Peopl	e exposed	on boat					
Events											Conseque	nces Bride	10	Conseque	nces Boat										
1	2	3	4	5	- 6	7	8	9	10	111		13	14	Fal5ity	*6	17	18	19	20	18	19	20	21	22	23
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots			Pipelin	<b>.</b>	Frequency	Outcoms		Rate from pool and jet fire exposure on bridge	No. of	PLL	Rate from pool and let fire exposure on boat	No. of	PLL	Boat Colkision Glanding Fatality Rate	No. of	PLL	Boat Collision Head On Fatality Rate	No. of		Total No.	Total PLL	
												18			210			210			210				T.,,,,,,
						0.5 y	0.3 y 0.7		Pipeline ruptures (NG or WO) Fatakijes from jet pool fire & collision Fatakijes from head on collision only Speed assumed to be >=8 knols	þ	1	16		0.25	52.E					0,2	42 42		110.5		
					У	0.5	. п		Fatalities from head on collision only	ь										0.2	42		42		1
				0.0018 head on	1	n		9.216-08	Speed assumed to be >=8 knots Falables from head on collision only	1				1									Ì		
			1.0 y	0.33	'n				Speed assumed to be >=8 knots Fatalities from nudging fenders only	[										0.2	42	3.878-06	42	3.87E-06	8 21E-08
	0.02 y	- · · · · · · · · · · · · · · · · · · ·		nudge 0.67 minor giano	·			}	Speed assumed to be >=8 knots Fatakies from glancing lenders only Speed assumed to be >=8 knots	ď															
390			0 05					]	Sevete glancing impact onto structure Speed assisted to be 4 knote [Pipelite topixes (NO or WO)	•															
0,0025641						0.5	03.	l	Fatalities from jet pout fire & outraton	•		10	0 25E 08	0.26	02.6	2 051 07				0.2	42	7 D.1L DB	110 4	3 38E Q7	1 671, 08
0.0023041					11	y	0.7 n		Fatalities from head on collision only Speed assumed to be >=8 knots	Þ										0.2	42	1 64E-07	42	1 84E-07	3.91E-08
- 1				0.0018	y	0.5			Fatailies from head on collision only Speed assumed to be >=8 knots	ь										0.2	42	2 34E-07	42	2 34E-07	5 58E-08
İ			0.95	head on	<u> </u>				Fatalities from head on collision only Speed assumed to be >=8 knots	Þ										0.2	42		42		
			y	0.33				2.06E-08	Falalities from sudging fenders only	c			i												l
i	ſ	0.0028 y		nudge 0.67 ninor glanc	4			4.13E-06	Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots	đ															
L	0.98 n	l	0.05 B					3.26E-07	Severe glancing Impact onto structure Speed assumed to be 4 knots	•															l
	L	0.9974 n							Boat passes under bridge	1												1			
			Outcomes			C+	ask e	9.60E-08 2.56E-03				- <del></del>													
			Carconde			UII	CUR SUM	COO!												-	···········		Total PLL	4.60E-08	*

Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots

Giancing collision > 8 knots

Severe glanding impact onto structure, LOP

Straight through

Event tree for passage through Fremantle Bridge
Boat Name : <u>Vessel 2</u>
Code V2 DO1 D
Design Option 1 Addition of dolphin: Addition of dolphins and fender strengthening

The second bearing bea

People exposed on boat

Downstream	tream of bridge, travelling from the harbour												Peopl	e exposed	on bridge			Immediate		o capasco	.,					
Events												Conseque	ness Bridg	je	Conseque	nces Boat	:									
1	2	3	4	5	6	7	8			10	11	F21201	13	14	F-15ity	18	17	18	19	20	18	19	20	21	22	23
Frequency	Sirikes Nav Soan		Strikes at speed greater than 4 knots		Causes Siructura I failure	Pipelic	ne en	on Frenk	BOCY	Outcome		Rate from pool and jet fire exposure on bridge	No. of	PLL	Rate from pool and jet fire exposure on boat	No. of	PLL	Boat Collision Glancing Fatality Rate	No. of	PLL	Boat Collision Head On Fatality Rate	No. of	PLL	Total No.	Total PLL	Freq
				5.75		1 100101	- 134					tar and a	18	1	- Circust	210	,	1 1/11/0	210		Litato	210		OI INCAMING	1 TOWN IT EL	<u>(194</u>
390	0.004 y	-	1.0 y	0.0018 head on 0.33 nudge 0.67	n	y n	0.3 y 0.7 n	1.75 3.24 6.48 5 13 3.41	E-08 E-06 E-08 E-07	Pipcine ruptures (NG or WO) Fatabiles from let pool fire & collision Fatabiles from head on collision only Speed assumed to be ≥=8 knots Fatabilles from head on collision only Speed assumed to be >=8 knots Fatabiles from head on collision only Speed assumed to be >=8 knots Fatabiles from medging fenders only Speed assumed to be >=8 knots Fatabiles from glancing fenders only Speed assumed to be ≥=8 knots Fatabiles from glancing fenders only Speed assumed to be ≥=8 knots Eatabiles from glancing fenders only Speed assumed to be ≥=8 knots Eatabiles from glancing fenders only Speed assumed to be ≥=8 knots Eatabiles from glancing fenders only Speed assumed to be ≥=8 knots Fatabiles from glancing fenders only F	* 4 0 0 d 4 a	1	16 16	1 27 <b>5</b> -0	0.5	105	8.35E-07		210		0.2 0.2 0.2 0.2	42 42 42 42 42	7 37E-07 1 43E-07	163 42 42 42		1 75E-08
0,0025641						<del></del>	- y 0.7	7,95		ratalities from jet, pool fire & collision Fatalities from head on collision only	Ь										0.2	42	3,34E-07	42	1 346-07	7.95E-09
					1		n		:	Speed assumed to be >=8 knots	<b>.</b>												5.5 1E-07		0.576-07	7.032-08
1				0.0018	y	n		┺.	!	Fatalities from head on collision only Spead assumed to be >=8 knots											0.2	42		42		
			0.95	head on	<u> </u>					Fatalilles from head on collision only Speed assumed to be >=8 knots	ŀ										0.2	42		42		
			, , ,	0.33				→ <sup>2.10</sup>		Fatalities from nudging fenders only Speed assumed to be >=8 knots	°				]											
Į	1,00 n	0.0026 y 0.9974		0.67 minor gland	e			3.321	-06 -07	special assumed to be 7-8 mins.  Speed assumed to be >=8 knots.  Severe planning impact onto structure.  Speed assumed to be 4 knots.  Boat passes under bridge.	d e															
	,	n	Outcomes			c	hack si	2.55I	-08		ľ —	w.w.			<u></u>		··						<del></del>	<u> </u>	2 405 70	

a Natural gas / Oil pipeline

Head on collison > 8 knots

Head on coason > 8 knots
Nudging collision > 8 knots
Glancing collision > 8 knots
Severe glancing impact onto structure. LOP
Straight through

Total PLL 2.18E-08

The state of the s

Event tree for passage through Fremantie Bridge

Boat Name: Vessel 2
Code V2 DO2 UP
Design Option 2 Widening of navigation spans

People exposed on boat

Upstream of	bridge, I	travelling	into the harb	our								Peopl	o bazoqxa ol	n bridge			Immediate		e exposeo	on doat					
Events											Conseque	nces Bride	20	Conseque	nces Boat										
1	2	3	4	5	6	7	8	9	10	11		13	14	F-15au	16	17	18	19	20	18	19	20	21	22	23
1	Strikes Nav	Strikes Non Nav	Strikes at speed greater than		Causes Sinuclura	Pipeline	,				Rate from pool and jet fire exposure	No, of		Rate from pool and jet fire exposure	No. of		Boat Collision Glancing Fatality	No. of		Boat Coxision Head On Fatakty	No. of		Total No.		
Frequency	Span	span	4 knots	bridge	lailure	ruplure	Ignition	Frequency	Outcome	_	on bridge		PLL	on boat	fatalities	PLL	Rate	fatalilies	PLL	Rate	falalities	PLL	of falables	Total PLL	Freq
							0.3	<u></u>	Pipeline ruptures (NG or WO)	a	1	18 16		0.25	210 52.5			210		0.2	210 42		110 5		
						0.5 Y	0.7		Falaities from jet, pool fire & colision Falaities from head on colision only Speed assumed to be >=8 knots	ь										0.2	42		42		
				0.0018	У	0.5			Fataities from head on collision only  Speed assumed to be >=8 knots	ь		•								0.2	42		42		
			1.0	head on	<u> </u>			8.33E-09	Fatalities from head on collision only Speed assumed to be >= 8 knots	b										02	42	3.50E-07	42	3.50E-07	8.33E-0
F-	0.002		y	0.33 nudge				l	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
390	y		0.05	0.67 minor gland			·		Fatakiles from glancing fenders only Speed assumed to be >=8 knots	ð															1
390			n		-		0.3		Severe glancing impact onto structure Speed assumed to be 4 knots Pipelina ruptures (NG or WO)	•		16	2.12E-08	0,25	50.5										
0.0025641					ı	0.5 y	y 0.7		Fatalities from jet pool fire & collision Fatalities from head on collision only	ь	•	10	2.126-08	0.25	52.5	6 97E-D8				0 2 0.2	42	2.39E-D8	110,5	1.15E-07	
					- <del>1</del> -	0.5	n		Speed assumed to be >=8 knots Fatalities from head on collision only	þ										0.2	42 42	5.58E-08 7.96E-08	42 42	5.58E-08 7.96E-08	
			0.95	0.0018 head on		n			Speed assumed to be >=8 knots Fatalities from head on collision only	b										0.2	42	7 202-08	42	7.802-08	1.802-0
			у у	0.33 nudge	n			7.01E-07	Speed assumed to be >=8 knots Fatalities from nudging fenders only Speed assumed to be >=8 knots	c													_		
	ſ	0.0009 y		0.67 ninor glanc				1.40E-08	Fatalities from glancing fenders only Speed assumed to be >=8 knots	ď															
L	1.00 n		0.05 n						Severe glancing impact onto structure Speed assumed to be 4 knots	e															
	L	0.9991 n	**************************************						Boat passes under bridge	ſ												;			
			Outcomes			Che	eck sum[	9.66E-09 2.56E-03 cool	-								·		٠.	—w			Total PLL	6.00E-07	L

a Natural gas / Oli pipeline
b Head on collison > 8 knois
c Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure. LOP

Straight through

Secretary Secretary Secretary Secretary Secretary Secretary Secretary Secretary Secretary Secretary Secretary

Event tree for passage through Fremantie Bridge

Boat Name: Vessel 2 Code VZ DOZ D

Design Option 2 Widening of navigation space

Downstream of bridge, travelling from the harbour

People exposed on boat

People exposed on bridge Immediate Consequences Bridge Consequences Boat 10 Fal Air 13 E-15ilu 16 17 18 19 20 10 19 מכ 21 22 23 Rate from Sale from Boat Boat Strikes of pool and post and Collision Colision Causes Gas/Oil Sidkes Skikes speed Jel fire let fire Głancinu Head On Non Nav greater than Strikes Structura Pipeline exposure No. of No. of Falality Fatality BXDDAWS No. of No of Total No. 4 finals I failure rupline ignition Frequency Outcome on bridgo falalilas falakijus of falables Total PLL on boat falafiles Rate finte falables Freq 210 210 210 Pipeline motures (NG or WO) 16 0.5 105 0.2 42 163 y 0.7 Falaities from jet pool fire & colision Fatalties from head on collision only 0.2 42 42 Speed assumed to be >=8 knots Fatalities from head on collision only 42 nσ 42 0.0018 Speed sesumed to be >=8 knots head on Fatalliles from head on collision only 0.2 47 3 50E-07 42 3 50E-07 8 33E-06 Speed assumed to be >=8 knots 0.33 Fatalities from nudging fenders only 0 002 nudan Speed assumed to be >=8 knots D 67 3 DBE-05 Falaities from glancing fenders only milior plance Speed necessed to be >=8 knots 390 Severe plancing impact only simplice Speed spenned to be 4 km/s Proeting ruotises (NG or WO) 4.25E-08 2 79E-07 0.5 105 4 78E-08 3 69E-07 1.14E-00 y 0.7 Fatalities from jet pool fire & collision 0.0025641 2.65E-09 Fatalities from head on collision only 1.12E-07 0.2 42 42 1.12E-07 2 85E-09 Speed assumed to be >=8 knots Fatalities from head on collision only Q.2 42 0.0018 Speed assumed to be >=8 knots head on Fatalities from head on collision only 02 42 Speed assumed to be >=8 knots 0.33 Fatalities from nudging fenders only nudge Speed assumed to be >=8 knots 0.67 1.40E-06 0.0009 Fataities from glancing fenders only minor glance Speed assumed to be >=8 knots 1.11E-07 Severe glancing Impact onto structure Speed assumed to be 4 knots 2.56E-03 | Boat passes under bridge Outcomes Check sum 2,56E-03 Total PLL 8.30E-07

> Natural gas / Oil pipeline Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure, LOP

Straight through

The state of the s

Event tree for passage through Fremantie Bridge

Book Name : <u>Vassel 3</u>
Code V3 DO1 UP
Design Option 1 Addition of delphins and fender strengthening

People exposed on boat

stream	f bridge,	gnikeyen	into the harb	our								People	e exposed o	n bridge			Immediate		e exposed	on ough					
ents											Conseque	nces Bridg	30	Conseque	nces Beat										
1	2	3	4	5	6	7	8	9	10	11	Fal Zily	13	14	Fal5ity	16	17	18	19	20	18	19	20	21	22	2
	Strikes Nav		greater than			Pipeline	.]				Rate from pool and jet fire exposure	No. at		Rate from pool and jet fire exposure	Na, of		Boat Collision Glancing Fatality	No. of		Boat Collision Head On Fatality	No. of		Total No.		
edneuch.	Span	span	4 knots	bridge	I failure	rupture	Ignition	Frequency	Outcome	<u>L</u>	ephist no	falailles	PLL	on boat	fataitles	PLL	Rate	falallies	PLL	Rate	fatablies	PLL		Total PLL	Fre
										_		16			225			225			225	•			
						0.5	<u>0,3</u> 		Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collision	a	1	16		0,25	56.25					0.2	45		117.25		
						у	0.7	1	Fataitles from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
				0.0018	У	0.5 n			Fatalities from head on collision only Speed assumed to be >=8 knots	ь										0.2	45		45		
			1.0	head on	1			9.21E-08	Fatalities from head on collision only Speed assumed to be >=8 knots	ь										0.2	45	4 14E-06	45	4 14E-06	9.2
	0.02		У	0.33 nudge				1.70E-05	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
	у		1 .	0.67				3.40E-05	Falaities from glancing fenders only Speed assumed to be >=8 knols	d															
390			0.05					2.69E-06	Severe glancing impact onto structure Speed assumed to be 4 knots	•															
			••			0.5	0.3	1,67E-09	Pipeline ruptures (NG or WO) Fatalities from let pool fire & collision	a	1	16	6.25E-08	0,25	56.25	2.20E-07				0.2	45	7.53E-08	117,25	3.58E-07	1.6
25641					.	y	0.7		Fatailles from head on collision only	b										0.2	45	1.76E-07	45	1.76E-07	3.5
				0.0040	y	0.5	n	5.58E-09	Speed assumed to be >=8 knots Fatalities from head on collision only	ь										0.2	45	2 51E-07	45	2 51E-07	1
			0.95	0,0018 head on		n			Speed essumed to be >=8 knote Fatalities from head on collision only	þ				•						02	45		45		
			V.93	0.33	n			2.06E-06	Speed assumed to be >=8 knots Falabiles from audging fenders only	¢															
,		0.0026		nudge 0.67					Spead assumed to be >=8 knots Fatalities from glancing fenders only	d					٠										
Ì	0.98	у	0.05	minor gland	e 			3.262-07	Speed assumed to be >=8 knots Severe glancing impact onto structure	e													•		
	n	0.9974	n					2.50E-03	Speed assumed to be 4 knots Boat passes under bridge	1															l
		ń	0.4					9.00E-08		 															l
			Outcomes			Ch	eck sum	2.56E-03										. 71					Total PLL	4.93E-06	
				a	Natural ga	s / Oil pl	pešne																		

Natural gas / Oil pipeline Head on collison > 8 knots

Nudging colision > 8 knots

Flooring coasion > 8 knots
Glancing coasion > 8 knots
Severe glancing impact onto structure, LOP
Straight through

Boat Name : Vessel 3 Code V3 001 D

0.0025641

Design Option 1 Addition of dalphins and fender strengthening

Downstream of bridge, travelling from the harbour

0.0026

0.9974

Outcomes

People exposed on bridge

People exposed on boat

Immediate

	-		_																						
Events											Conseque	rces Bridg		Conseque	nces Boat										
11	2	3	4	. 5	6	7	8	9	10	11	Fallally	13	14	F=1500	16	17	18	19	20	18	19	20	21	22	23
Frequency		Strikes Non Nav	Strikes at speed greater than 4 knots			Pipeline	4	Frequency	Outcome		Rate from pool and jet fire exposure on bridge	No, of	PŁL	Rate from pool and jet fire exposure on boat	No. of	PLL	Boat Collision Glancing Fatality Rale	No. of	PŁŁ	Boat Collision Head On Fatality Rate	No. of	PLL	Total No.	Total Di I	Freg
					***********							18			225	, ,	11010	225		, Note	225	1	O I INCOME IOS	10tal FEL	- 1164
		ĺ	1,0 y	0.0018 head on 0.33		1 y	0.3 y 0.7 n	1.75E-08 3.24E-06	Pipeline ruplures (NG or WO) Falakiles from jet, pool fire & collision Fatakiles from head on collision only Speed assumed to be ≥=8 knots Falakiles from head on collision only Speed assumed to be ≥=8 knots Falakiles from head on collision only Speed assumed to be ≥=8 knots Falakiles from head on collision only Speed assumed to be ≥=8 knots Falakiles from pudging lenders only	а b b	1	16		0.5	112.6					0 2 0.2 0.2 0.2	45 45 45 45	7 89£-07	173.5 45 45 45	7.895-07	1 75E-08
300	0.004 y		0.05	nudge 0.67 ninor gland	:0			6.48E-06	Speed assumed to be >≃8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Severe glancing impact onto structure	8															
,			rı '		****		63	3 41E-00	Spend assumed to be 4 knote  Pipeline replaces (NO or Wo)  Falables from let pool for 8 collision		1	10	1 2/£ 0/	0.6	1125	0 V4L-0/				02	45	1 631 67	1/36	1 17E-00	3 41E 00

Natural gas / Oil pipeline Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure, LOP

2.55E-08 Check sum 2.56E-03

cool

y Falaities from jet pool fire 5 collision 0.7 7.95E-09 Fatalities from head on collision only

Falaklies from jet pool fire & colksion

Speed assumed to be >=8 knots Fataitles from head on collision only

Speed assumed to be >=8 knots Falaülies from head on collision only

Speed assumed to be >=8 knots 2.10E-06 | Fatalities from nudging fenders only

Speed assumed to be >=8 knots

Speed assumed to be >=8 knots 3.32E-07 Severe glancing impact onto structure Speed assumed to be 4 knots 2.55E-03 Boat passes under bridge

4.20E-08 Fatalities from glancing fenders only

Straight through

0.0018

nudge

0.67

minor ofance

Total PLL 2.32E-06

45

3 58E-07 7.95E-09

3 58E-07

45

45

45

0.2

02

0.2

Branch Branch Francisco Control Contro

Event tree for passage through Fremantle Bridge

Boal Name: <u>Vessel 3</u>
Code V3 DO2 UP
Dasign Option 2 Widening of nav
Upstream of bridge, travelling into the harbour Widening of navigation spans

People exposed on boat

People exposed on bridge

Immediate	
-----------	--

Consequences Bridge	19 20	21 22
Strikes   Stri		21 22
Strikes   Stri		
D.3	No. of fatablies PEL	Total No. of fatalities Total PLL
0.5   y   Fatalities from led, pool fire & collision only   Speed assumed to be >= 8 knots   Spee	225	
Description	45	117.25
0.0018	45	45
1.0	45	45
0.002   nudge   Speed assumed to be >=8 knots     y	45 3 75E-03	7 45 3.75E-07
Speed assumed to be >=8 knots		
Speed assumed to be 4 knots   Speed assumed to be 4 knots   Speed assumed to be 4 knots     0.3   S.69E-10   Pipeline ruptures (NG or WO)   a 1 16 2.12E-08   0.25 56.25 7.47E-08   0.2     0.0025841   y 0.7   1.33E-09   Fatalities from head on collision only   b   0.2     1   n   Speed assumed to be >=8 knots   0.2		
0.5 y Fatalities from led pool fire & collision y 0.7 1.33E-09 Fatalities from head on collision only to 1 n Speed assumed to be >=8 knots 0.2		
1 n Speed assumed to be >=8 knots	45 2.56E-08	8 117.25 1 22E-07
	45 5 97E-08	
0.0018   y   0.5   1.90E-09   Fatalities from head on coxision only   b   0.2	45 8 53E-08	8 45 8.53E-08
O.3  Palables from head on collision only  D.33  Palables from nudging fenders only  D.33  7.01E-07   Falables from nudging fenders only  C	45	45
nudge   Speed assumed to be >=8 knots		
y minor grance Speed assumed to be >=8 knots  1.00 0.05 1.115-07   Severe glancing impact onto structure   e		
5 Speed assumed to be 4 knots 0.8991 2.56E-03 Boat passes under bridge f		
9.66E-09		
Outcomes Check sum 2.56E-D3 cool		Total PLL 6.41E-07

Natural gas / Oil pipeline Head on collison > 8 knots

Head on coason > 8 knots
Nudging colision > 8 knots
Glanding colision > 8 knots
Savere glanding impact onto structure. LOP
Straight through

Event tree for passage through Fremantle Bridge

Boat Name : <u>Vessel 3</u> Code V3 DO2 D

Design Option 2 Widening of navigation spans People exposed on boat

Downstream	nstream of bridge, travelling from the harbour											People	е ехрозеб о	n bridge			Immediate		·						
Events											Conseque	ncas Bridg		Conseque	nces Bart										
1	2	3	4	5	_6	7	8	9	10	11	F-1700	13	14	Fal5ity	18	17	18	19	20	18	19	20	21	22	23
E	Strikes Nav Span	Strikes Non Nav	Strikes at speed greater than 4 knots	Strikes bridge		Pipelin	d .	Frequency	Ostroma		Rate from peol and jet fire exposure on bridge	No. of falaillos	PLL	Rate from pool and jot fire exposure on boat	No. of	PLL	Boat Collision Glancing Fatality Rate	No of	PLL	Boat Collision Hoad On Fatality Rate	No of	PLL	Total No.	Total PLL	Freq
Frequency	Span	Phan	1 4 1006	i ciloye	1 terithan	1 respices	Filemani	II r (oqueinc)	Cancollis	1	OH DROSE	18	1 (62	OH BORE	225		11/210	225	,,,,,		225	1	]	T TOISIT LL	1754
				0.0018	7	1 y	0.3 y 0.7 n		Pipeline nuptures (NG or WO) Fatalities from jet, pool fire & collision Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be > 5 knots	a b b	1	16		0,5	112.5					0 2 0.2 0.2	45 45 45		173 5 45 45		
390	0,602 y		1.0 y	0.33 nudge 0.87 minor gland	<u> 1</u>			1.54E-06 3.08E-06 2.44E-07	Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from nudging fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Gavers plancing to be >=8 knots Gavers plancing to pad only structure	b c d										0.5	45	3 75E-07	45	3.75E-07	8 33E-09
0.0025641					<del>- 1</del>	<del>,</del>	y 0.7 n		If justime righters (NC to WO) Fatalities from let pool fire & collision Fatalities from head on collision only Speed assumed to be >= 8 knots Fatalities from head on collision poly	# b	1	10	4 281 08	110	1120	7 901 07				0.2 0.2	45 45	n 131 (IA 1 19E-07	1/3 6 45 45	3 M7E-07	1 546; (19 2 85E-09
			0.95 y	0.0018 head on 0.33 nudge		n		7.01E-07	Speed essumed to be >= 8 knots Fatalities from head on collision only Speed assumed to be >= 8 knots Fatalities from nudging fenders only Speed assumed to be >= 8 knots	ь с										02	45		45		
ļ	1.00 n	0.0009 y 0.9991	0.05 n	0.87 minor gland	ce			1.11E-07 2.56E-03	Fatakties from glancing fenders only <u>Speed assumed to be &gt;=8 knots</u> Severe glancing impact onto structure <u>Speed assumed to be 4 knots</u> Boat passes under bridge	d e f				7 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2											
			Outcomes			C	reck sum	1.10E-08 2.56E-03	]			<del>, , , , , , , , , , , , , , , , , , , </del>			*****************	<del></del>			<del>/////////////////////////////////////</del>				Total PLL	8.87E-07	1

Natural gas / Oil pipeline

Head on collison > 8 knots Nudging collision > 8 knots Glancing collision > 8 knots

Severe glancing impact onto structure, LOP Straight through

cool

Bost Harne: <u>Vessel 4</u>
Code V4 DD1 UP

Design Option 1 Addition of dolphins and fender strengthening

Committee of Benefits of Benef

People exposed on boat

Upstream of	f bridge, i	i gnillevari	nte the harb	OUF								People	e exposed o	n bridge			Immediate								
Events											Conseque	nces Bridg	В	Conseque	nces Boat										
1	2	3	4	5	6	7	8	9	10	11	Falkin	13	14	F21500	16	17	18	19	20	18	19	20	21	22	23
						i			·		Rate from		•	Rate from			Boat			Boat				1	1
l i			Strikes at							1	pool and			pool and		1	Collision			Collision		1			Į.
l i	Strikes	Strikes	speed	ļ.		Gas/Oll				1	jet fire		ŀ	jet fire			Glancing			Head On				Ì	[
1_ 1	Nav		greater than		Structura					1	exposure	No. of		exposure	No. of	ŀ	Fatality	No. of		Fatality	No. of		Total No.		1
Frequency	Soan	span	4 knots	bridge	t failure	rupture	tonition	Frequency	Outcome	ᆫ	on bridge		PLL	on boal	falalities	PLL	Rale	fataklins	PLL	Rate	_fatalities	PLL	of fatalities	Total PLL	Freq
												16			200			200			200				
							D.3		Pipeline ruptures (NG or WO)	Ta	1	18		0.25	50					0 33	66		132		
						D.5	y		Falalilles from jet pool fire & collision	.[										9.55	•••				
						У	0.7		Falailles from head on collision only	]b										0.33	68		66		1
						j	n		Speed assumed to be >≃6 knots	1													''		
					y	0.5			Fataliles from head on collision only	р										0.33	68		68		1
				0.0018	1 .	n			Speed assumed to be >=8 knots	4.															
			1.0	hezd on	<u> </u>	<del></del>		4.60E-08	Fatalities from head on collision only	þ										0.33	66	3 04E-06	68	3.04E-08	4.60E-08
				0.33	n			0.612.00	Speed assumed to be >=8 knots Fatalities from nudging fenders only	┨_				}											
	0.02		y	nudge			-		Speed assumed to be >=8 knots	۴															1
E	У			0.67			- 1		Fatalities from glancing fenders only	1,				ł											1
Ī	•		١,	ninor gland	ė				Speed assumed to be >=8 knots	ľ															ľ
780			0.05						Severe glancing impact onto structure																
			ת						Speed assumed to be 4 knots	J															ļ
- 1							0,3	8.37E-10	Pipeline ruptures (NG or WO)	a	1	16	3.12E-08	0.25	50	9.77E-08				0.33	86	5.52E-08	132	1.84E-07	8.37E-10
						0.5	y		FataSties from jet,pool fire & collision	1				ļ											
0.0012821						y L	0.7		Fatalities from head on collision only	b										0.33	66	1.29E-07	66	1.29E-07	1.95E-09
- 1						l	n		Speed assumed to be >≃8 knots	1.													l		1
- 1				0.0018	у.	0.5 n		2.798-09	Falailles from head on collision only	Þ										0.33	68	1.84E-07	66	1.84E-07	2 79E-09
- 1			1	head on		n	ŀ		Speed sesumed to be >≃8 knote Fataxties from head on collision only	l.													ŀ		ĺ
			0.95	11040 511	n.				Speed assumed to be >=8 knots	ľ										0 33	66		88		
		ſ	y	0.33	••		ı	1.03E-06	Fatalities from nudging fenders only	l.															l
				nudge	******		$\neg \neg$		Speed assumed to be >≃8 knots	ľ															İ
		0.0026		0.67				2.08E-08	Fatalities from glancing fenders only	la															l
- 1	- 1	y		ninor glanc	£				Speed assumed to be >=8 knots																ĺ
Ŀ	0.98	1	0.05						Severe glancing Impact onto structure	e												j			1
	U		Ð				l.		Speed assumed to be 4 knots	ı			j												İ
	L	0.9974						1.25E-03	Boat passes under bridge	1															ĺ
		В					L		· · · · · · · · · · · · · · · · · · ·	1															İ
			0.4			<b>D</b> b		4.80E-08																	İ
			Outcomes			Che	ck sum [	1.28E-03															Total PLL	3.54E-06	

Natural gas / Oif pipeline Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure, LOP Straight itwough

puquo tions + rrequency Structural Pipeline Sinker Nert Telsarg Velt from Causes Gas/Oil peads Slykes ZEKINES Sidkes at 6 Downstream of bridge, traveling from the harbour gninedignetiz tebrist bas znirigiob to noikbbA L notigo ngised COQ# A4 DO4 D ACSSOL 4 Soat Marrie Event tree for passage through Fremantle Bridge

บดีกดูเลา รบดีเยาเจ

Outcomes

50'0

6.95

minor glance

500m

0.33

A100.0

**7285'0** 

9200 0

1,00

Severe general impact and structure, LOP Glancing collision > 8 knots MIGGING CONSIDU > R KUDIS Head on collison & Knots ougodid tio / seg lewien

Check sum 1.28E-03

1.27E-08

1,27E-03 Soal passes under unage

SIGUA & 60 OI DOMNESS BERG 1.66E-07 | Severe giancing impact onto structure

2. 10E-06 Falabiles from glanding fenders only

Speed assumed to be >=8 knots

Speed accumed to be >=8 knots 1.05E-06 Falakites from mudging fenders only

Stored account of bernusse bands

slond 8=< ad of bemuses bead

sisting from head on collision only

stabiles from head on collision only SHOUN Pres and of paulmage pands

The second of th

Falshies from head on collecton only T.0 0.0012821 noisides from jet pool for & colision 6 70E-07 1 70E 09 70-46L L CC U 20 120 C GCI 90 10 0.30E-08 Pipaline ruptures (NG or VVO) 60-30/1 Co. Stotis + an of Detribes beatle 2 50H-07 Severe glancing inquet onto structure SDO 084 slow gac ed of bemuser beeds names Serve 3.24E-06 Falalites from glancing fenders only **49'0** stona B=< ad of barrace beag efionu 100 O 1.62E-06 Fatabiles from nudging tenders only CC'0 Speed assumed to be >=8 knots 60-347.8 T0-387 è 20-962'9 ££ 0 8.77E-09 Fatalties from head on collecton only no besd sloud Bac ed of bemuses bead 8100.0 ga ££.0 Falabiles from head on collision only Store as sumed to be 5=6 lines EE.O stakiles from head on colision only χ Σ'Ο noisitos & siñ lood, fel most sellikele: 7 R L 99 66.0 OQ! **6.0** 91 L Pipeline ruptures (NG or WO) 007 Freq AJS INDE ROUBLES TOLD e ilia si si 1 fallore | rupture | Ignition | Frequency | Outcome ou olidãe 40(18년)라 Tolsi No. 10,01 Villele? to .oN FRIBITY No. of expsodx: 10.01 eunsudxa Nesd On Bujaueja etā jeļ elf fire CONSIDER CONSIDIO OUR IGOR puz Jood 1soA 1so2 mon als A Rate from METER II शङ्कारत 23 22 53 50 бl 18 £ŝ 8:-٥r Consequences Boat Consednences Budge

People exposed on bridge

££.0 66.0 2 62E-07 3 07E-08 2 82E-03

alsibamml

People exposed on boat

1041 PLL 1.41E-08

Bearing Parameter Proposed Recognition Proposed Rec

Event tree for passage through Fremantle Bridge Boat Name : <u>Yessel 4</u> Code <u>V4 D02 UP</u> Design Option 2 <u>Widening of naviga</u>

Widening of navigation spans

People evented on host

Jpstraam of			into the hart		on spans							Peopl	le exposed o	n bridge			Immediate		e exposed	on boal					
Evants											Conseque	nces Bride	18	Conseque	neac Boxt										
1	2	3	4	5	6	7	. 8	9	10	111	Fa1200	13	14	Fa/5	16	17	18	10	20	18	19	20	21	22	23
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes	Causes Structura I fallure	Pipeline	fanillon	Frequency	Oulcome		Rate from pool and jet fire exposure on bridge	No. of	PLL	Rate from pool and jet fire exposure on boat	No of	PLL	Boat Collision Glancing Fatality Rale	No. of		Boat Collision Head On Fatality	No of		Total No.		
			^~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~								T. on anago	16	1 725	USTOUR	200	1 FLL	{ Raie	falables 200	PLL	Rate	fatalities 200	PLL	of falailites	Total PLL	Freq
780 0.0012821	9.002 y	<u>0 0009</u>	0.95 y	0.0018 head on 0.33 nudge 0.67 minor glanc	1 y	0.5 y 0.5 n	n	7.70E-07 1.54E-06 1.22E-07 2.84E-10 6.84E-10 9.48E-10 3.51E-07 7.01E-07	Pipekine ruptures (NG or WO) Fatalities from let pool fire & collision Fatalities from let pool fire & collision Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from nuclping fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Severe glancing impact onto structure Speed assumed to be >=8 knots Fatalities from fel pool fire & collision Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from mudging fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only	a b b b c d e a b b b c d e	1	16	1.06E-08	0.25	50	3.32E-08				0.33 0.33 0.33 0.33 0.33 0.33	66 66 68 68 66 68	2.75£-07 1.88£-08 4.38£-08 6.28£-08	132 66 68 66 132 66 66	2.75£-07 6.26£-08 4.38E-08 6.26£-08	2.84E-1 6.84E-1
		0.9991	п				ŀ		Speed assumed to be 4 knots Boat passes under bridge	Į,															
		n	Outcomes	-		Che	ck sum	4.83E-09 1.28E-03	nes hesses amet bunde	]' —										77.4	****				
								copt															Total PLL	4.44E-07	

cool
Natural gas / Oil pipeline
Head on colison > 8 knots
Nudging colision > 8 knots
Glancing colision > 8 knots
Severe glancing impact onto structure, LOP
Straight through

Francisco Franci

Every tree for passage through Fremantle Bridge

Event tree for passage through
Boat Name: <u>Vessel 4</u>
Code V4 DO2 D
Besign Option 2 Widening of navigation spans

People exposed on boat

Downstream	stream of bridge, travelling from the harbour											Peopl	e exposed o	n bridge			Immediate		c caposco .						
Events											Conseque	nces Bridg	7◆	Conseque	nces Boat										
1	2	3	4	5	-8		В	9	10	11	E-7200	13	14	F-15au	18	17	18	19	20	18	19	20	21	22	23
Frequency	Sirikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structure I failure	Pipeline	]	n Frequency	Oulcome		Rate from pool and jet fire exposure on bridge		PLL	Rate from pool and jet fire exposure on bost	No, cf	PLL	Boat Collision Glancing Fatality Rale	No. of	PLL	Boal Collision Head On Falally Rale	No. of falakties	PLL	Total No	Total PLL	Freq
												16			200			200			200	-			
						1 y	0.3 y 0.7		Pipeline ruptures (NG or WO) Falablies from let pool fire & collision Falablies from head on collision only	]	1	16		0.5	100					0.33	66		182		
						,	<u>0.7</u>		Speed assumed to be >=8 knots	ľ										0 33	66		66		
				0.0018	У	<u> </u>		-	Fatalties from head on collision only  Speed assumed to be >= 8 knots	b				1						0,33	68		66		
			1.0	head on	<u> </u>			4.176-09	Fatalties from head on collision only Speed assumed to be >=8 knots	ь										0 33	66	2 75E-07	66	2 75E-07	4 17E-00
	0.002		У	0.33 nuoge				7.70E-07	Fatalities from nudging tenders only Speed assumed to be >=8 knots	c													ł		
	y			minor gland	:e			1.54E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	٥				ļ		•									
780			L_0 <u>05</u>		· •			1 22E-07	Severe glanding impact onto structure Speed assumed to be 4 knots	•				İ											
						1	0.3 y	5 09E-10	Pipeline rightnes (NO or WO) Fatalities from jet pool fire & colleges	1	1	10	2 121-08	0.0	100	1 331, 67				0.23	00	3 751, 40	187	1 PZE 07	2 aht: 10
0.0012821					1	У	0.7 n	1.33E-09	Fatablies from head on collision only Speed assumed to be >=8 knots	•										0.33	66	8 76E-08	68	8 765-08	1 33E-09
				0.0018	У	<u> </u>			Falailins from head on collision only Speed assumed to be >=8 knots	ь										0 33	66		68		
			0.95	no been	<u></u>			-	Fatalities from head on collision only Speed assumed to be >=8 knots	ь										0 33	88		88		
			У	0,33 nudge				3.51E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	ŀ															
	1	0.0009 y		0.87 minor gland	e				Fatalilles from plancing fenders only Speed assumed to be >=8 knots	ď															
l	1.00 ก		0 <u>05</u>						Severe glanding impact onto structure Speed assumed to be 4 knots	·															
	l	0.9991 n						L	Boat passes under bridge	f															
			Oulcomes			Ch	eek eun	5.49E-09 1.28E-03	1	_													<u> </u>	E 645 07	

Natural gas / Oil pipeline Head on collison > 8 knols

Nudging collision > 8 knots Glancing collision > 8 knots

Severe glancing impact onto structure, LOP Straight through

Total PLL 5.54E-07

and be known to known

Event tree for passage through Fremantle Bridge

Event tree for passage through
Sout Name: Vessel 5
Code V5 DO1 UP
Design Option 1

Addition of dolphins and fender strengthening

People exposed on boat

e.		exposed		heide .	
	무미대를	exposed	013	Dauge	

Upstream of	bridge, i	travalling	into the harb	our								₽eople	exposed o	n bridge			Immediate								
Events											Conseque	nces Bridge		Conseque	nces Boat										
1	2	3	4	5	6	7	8	9	10	11	calativ	13	14	FalSity	16	17	18	19	20	18	19	20	21	22	23
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structura I failure	Pipeline	lanilian	Frequency	Outcome		Rate from pool and jet fire exposure on bridge	No. of	PLL	Rale from pool and jet fire exposure on boat	No. of	₽LL	Boat Collision Glancing Fatality Rate	No. of	PLL	Boat Collision Head On Fatality Rate	No. of	PLL	Total No.	Total DJ 1	
		11				استنتانها					,	16			142		1 11010	142	,,,,,	1 (/=10	142	FLL	U) Hatanties	TOTAL FLE	MIEQ
				0.0018	· Y	0.5 y 0.5	0.3 y 0.7 n		Pipeine ruptures (NG or WO) Fatabiles from jet poot fire & colision Fatabiles from head on colision only Speed assumed to be >=8 knote Fatabiles from head on colision only Speed assumed to be >=8 knote	В	1	16		0.25	35.5					0.2 0.2 0.2	28 28 28		79.9 28.4 28.4		
٦	0.02 y		1.0 y	head on 0.33 nudge 0.67	<u> </u>			8.51E-06	Speed assumed to be >= 8 knots Fatalities from head on collision only Speed assumed to be >= 8 knots Fatalities from rudging fenders only Speed assumed to be >= 8 knots Fatalities from gancing fenders only	- A										0.2	28	1.31E-06	28 4	1,31E-08	4.60E-08
780			0.05 n	minor gland	e	05.	0.3	1.35E-06	Speed assumed to be >=8 knots Severe glanding impact onto structure Speed assumed to be 4 knots Pipeline ruptures (NG or WO)	e	1	16		0.25	35.5					0.2	28		79.9		
0 0012821					j	0.5 y	y 0.7		Falailles from jet pool fire & collision Falailles from head on collision only Speed assumed to be >=& knots	ь										0.2	28		28 4		
ŀ				0.0018	у	0,5 N			Fatalities from head on collision only  Speed assumed to be >=8 knots	ь										0.2	28		28 4		
			0.05 y	head on 0,33	1 0			1,03E-06	Fatafiles from head on collision only Speed assumed to be >=8 knots Fatafiles from nudging fenders only	b c										0.2	28	1.58E-07	28 4	1.58E-07	5.58E-09
	ſ	0.0028 y		nudg <del>e</del> 0.87 ninor glanc	•			2.08E-06	Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
Ĺ	89.0 n	0,9974	0.05 n		···				Severe glancing impact onto structure Speed assumed to be 4 knots Boat passes under bridge	e															
		n					$\neg$	4.60E-08	coer besses guara guara	j'															1
			Outcomes			Che	ck sum{	1.28E-03						*									Total PLL	1,47E-08	

Natural gas / Oil pipeline Head on collision > 8 knots Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure, LOP Straight through

Event tree for passage through Fremantie Bridge Boat Name : <u>Vessel 5</u> Code V5 DO1 D

Design Option 1 Addition of dolphins and fender strengthening People exposed on boat

Downstream		o, traveli	Addition of ng from the h		₩ 1011U0	, suany	te to thirty					People	exposed o	n bridge			immediale		e exposed (	O/1 DOM					
Events											Conseque	nces Bridge	,	Conseque	nces Boat										
1	2	3	4	5	6	7	8	9	10	11	Fal Aitu	13	14	17a15ity	16	17	18	19	20	18	19	20	21	22	23
Er	Sirikes Nav Span	Strikes Non Nav	Strikes at speed greater than 4 knots	Strikes	Causes Structura	Pipelin	el	n Frequency	Cuttama		Rate from pool and jet fire exposure on bridge	No. of	PLL	Rate from pool and jet fire exposure on boat	No. of	PŁL	Boat Collision Glancing Fatality Rate	No. of	PLL	Boat Coäsion Head On Fataity Rate	No. of	PLL	Total No.	Total PLL	Freq
Frequency	Span	Span	4 R21015	i oriuge	I Harve	Topon	e į igranoi	of requency	Outcome		On billage	18	FLE	- Un Duar	142	FEL	(vala	142	- FLU	Nate .	142	, <i></i> LL	OI MACARLIES	LIDIALFCE	rieq
780	0.004 y		1.0 y	0.0018 head on 0.33 nudge 0.67 minor gland	<u>1</u>	1 y	0.3 Y 0.7 n	1,82E-08 3,24E-08	Pipeline ruptures (NG or WO) Fatalities from let, pool fire & collision Fatalities from let, pool fire & collision Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from nudding fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Fatalities from glancing fenders only Speed assumed to be >=8 knots Severa glancing impact on the unicities	a b b c d	1	16		0,5	71			192		0.2 0.2 0.2 0.2	28 28 28 28 28	2 40E-07	115.4 28.4 28.4 28.4 28.4	2 49E-07	8 77E-09
0.0012621	1.00 n	0.0026 y 0.9974	0.95 Y	0.0018 head on 0.33 nudge 0.67 minor gland	1_1_	y n	0.3 Y 0.7 n	5.68E-09 1.05E-06 2.10E-06 1.66E-07	Speed assumed to be 4 knote.  Pipetine ruptures (NG or WO)  Fatalities from let, nood fire & collision only.  Speed assumed to be >=8 knots.  Fatalities from head on collision only.  Speed assumed to be >=8 knots.  Fatalities from head on collision only.  Speed assumed to be >=8 knots.  Fatalities from head on collision only.  Speed assumed to be >=8 knots.  Fatalities from mudging fenders only.  Speed assumed to be >=8 knots.  Fatalities from glancing fenders only.  Speed assumed to be >=8 knots.  Severe glancing impact onlo structure.  Speed assumed to be > 4 knots.  Boat passes under bridge.		1	18		0.5	71					0.2 0.2 0.2 0.2	28 28 28 28	1.812-07	28.4 28.4 28.4 28.4	1.61E-07	5,88E-01
			Outcomes			C	heck sun	8.77E-09 1.28E-03	]					l	<del>,</del>							***	Total PLL	4.10E-07	L

Natural gas / Oil pipeline Head on collison > 8 knots

Nudging collision > 8 knots Glancing collision > 8 knots

Severe glancing impact onto structure. LOP Straight through

The second of th

Event tree for passage through Fremantie Bridge

Boat Name: Vessel 5
Code V5 DO2 UP
Design Option 2

Widening of navigation spans

People exposed on boat

Upstream of		travelling .	into the harb		-17.4113							People	exposed o	n bridge			Immediate		e exposeo	on DUAL					
Events											Conseque	nces Bridge	•	Conseque	nces Boat										
1	2	3	4	5	6	7	8	9	10	11	E-12:10	13	14	Fa15in	16	17	18	19	20	18	19	20	21	22	23
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge		Pipeli	ine	n Frequency	Очеств		Rate from pool and jet fire exposure on bridge	No. of Sataktles	PUL	Rate from pool and jet fire exposure on boat	No of	PLL	Boat Collision Glancing Fatality Rate	No. of falailies	PLL	Boat Collision Head On Falality Rate	No. of	PLL	Total No.	Total PLL	Freq
						<u>0.5</u> У			Pipeline ruptures (NG or WO) Fatalities from Jet pool fire & collision Fatalities from head on collision only	];	1	16 16		0.25	142 35.5			142		0.2 0.2	142 28 28		79.9 28.4		
				0.0018 head on		0.5 n	n	4 175 00	Speed assumed to be >=8 knots Fatakties from head on collision only Speed assumed to be >=8 knots Fatakties from head on collision only											0.2	28		28.4		
ſ	0.002 y		1.0 y	0.33 nudge 0.67	n			7.70E-07	Fatalities from nead on cossion only  Speed assumed to be >=8 knots  Fatalities from nudging fenders only  Speed assumed to be >=8 knots  Fatalities from glancing fenders only	C C										02	28	1 18E-07	28.4	1.18E-07	4.176-0
780	•		0.05	minor glan	ce		0.3		Speed assumed to be >=8 knots Severe glancing impact onto structure Speed assumed to be 4 knots Pipeline ruptures (NG or WO)	e	1	16		0,25	35.5					0.2	28		79.9		
0.0012821					<u> </u>	0.5 y 0.5	0.7		Fatalties from jet pool fire & collision Fatalties from head on collision only Speed assumed to be >=8 knots Fataltiles from head on collision only	b										0.2	28		28.4		
		i	0.95 y	0 0018 head on 0,33		n	· · · · · · · · · · · · · · · · · · ·	٦	Speed assumed to be >=8 knots Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from nudging fenders only	5										0.2	28 28	5.39E-08	28.4 28.4	5.39E-08	1.00E-
	1.00	0,0009 Y	0.05	nudge 0.67 minor gland	:			7.016-07	Speed assumed to be >=8 knots Fatalities from planning fenders only Speed assumed to be >=8 knots Severe glanning impact onto structure	ď															
	n	0.9991 n	0					1.28E-03	Speed assumed to be 4 knots Boat passes under bridge	,															
			Outcomes			ď	Check sur	4.17E-09 1.28E-03 cool	I					<u> </u>									Total PLL	1 72E-07	L

Natural gas / Oil pípeline Head on collison > 8 knots

Nudging collision > 8 knots Glancing collision > 8 knots

Severe glancing impact onto structure, LOP

Straight through

Event free for passage through Frementle Bridge Boat Name : <u>Vessel 6</u> Code V5 DO2 D Design Option 2 . Widening of navigation spans Downstream of bridge, travelling from the harbour

People av

People exposed on boat

exposed on bridge	lma
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DOMUZILEGI	n ot etted	e, traven	ing from the i	INDOUR								People	exposed o	n bridge			Immediate								
Events		<del></del>							_	-,		nces Bridge		Consequer	ices Boat										
1	2	3	4	5	6	7	8	9	10	11	F-1700	13	14	Fa1500	16	17	18	19	20	18	18	20	21	22	23
Frequency	Sirikes Nav Span	Strikes Non Nav		Strikes bridge	Structure	Gas/Oil Pipeline suplure	tonillen	Fraguency	Outcome		Rate from poot and jet fire exposure on bildes	No. of	PLL	Rate from pool and jul fire exposure on boat	No of	PLL	Boat Collision Glancing Falakty Rate	No. of	PLL	Boat Collision Flead On Falality Rate	No. of	PLL	Total No	Total Oil	Freq
						******						16	,		142		1	142	<del></del> .		142	11	Of the section is	I Inter LCC	1399
						. 1 [	0.3 y		Pipeline ruptures (NG or WO) Fatabiles from jet pool fire & coresion	]a	1	16		0,5	71					0 2	28		1154		
						ר ע	0.7 n		Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
				0.0018					Fatalities from head on collision only Speed assumed to be >=8 knots	Ь										02	28		28 4		
			1.0	head on	0		······	L	Falaitles from head on collision only Speed assumed to be >=0 knots	b										02	28	1 18E-07	28 4	1 16E-07	4 17E-00
1	0.002 Y		, y	0.33 nudge 0.67					Fatables from nudging fenders only Speed assumed to be >=8 knots  Fatables from glancing fenders only	ļ°.															
780	,		0.05	minor giano					Speed assumed to be >=8 knots  Severe planning impact onto structure	Ľ															
			0			. 1	0.5		Open expended to be 4 hinds Parelle rightee (NA in WO) Fatables from let push the & collision		ι	10		00	n					0.2	28		1104		
0.0012821						\ <del>\</del>	0.7 n		Fatakties from head on collision only  Speed assumed to be >=8 knots	b										02	28		28 4		
				0.0018	У				Fatatilies from head on collision only Speed assumed to be >=8 knots	ď										02	28		28.4		
			0.95 Y	head on 0.33	1 n				Fatalities from head on collision only Speed assumed to be >=8 knots	ľ										0.2	28	5 39E-08	28.4	5.39E-08	1.90E-0
İ		0.0009	, ,	nudge 0.67					Fatalties from nudging fenders only Speed assumed to be >=8 knots Fatalties from glancing fenders only	ľ															ļ
	1.00	у	0.05	ninor gland	e				Speed assumed to be >=8 knots Severe glancing impact onto structure																
1	n	0.9991	n					!	Speed assumed to be 4 knots  Boat passes under bridge	ľ															
		n	Outcomes			Che	ck sum	4.17E-09 1.28E-03	]		*****						~~~		·	*			Total PLL	1.72E-07	

more framed fram

Natural gas / Oil pipeline

Head on colison > 8 impts

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure, LOP

Straight (brough

Figure 1 Section 1 Section 2 Section 2 Section 2 Section 3 Section

Event tree for passage through Fremanile Bridge

Boat Name: Vessel 6
Code V5 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening

People emocad on best

pstream of		ravelling i	Addition of dash shi otol		ana tenaei	r strøngti	nening					People	exposad o	n bridge			Immediale	Peopl	e exposed	on boat					
vents											Consum	nces Bridge		Conseque	nras Rost										
1	2	3	4	. 5	- 6	7	8	9	10	11	F-1200	13	14	F-15-ty	15	17	18	19	20	18	19	20	21	22	1 -
requency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than thools	Strikes bridge	Causes Structura I fallore	Pipeline	Ignition	Frequency	Oulcome		Rate from pool and jet fire exposure on bridge	No. of	PLL	Rate from pool and jet fire exposure on boat	No o²	PL1	Boat Collision Glancing Falaily Rate	No. of	PLL	Boat Collision Head On Fatality Rate	No. of	PLL	Yotal No.	Total PLL	2:
												16			119.4			119.4		1	110		U. ZEIGHBO	T TOTAL P.C.	<del>  "</del>
						0.5	0.3 y		Pipeline ruplures (NG or WO) Fataklies from jet pool fire & collision	a	1	16		0.25	29 85					0.2	24		69.73		
						у	0.7 n		Fatalities from head on collision only Speed assumed to be >=8 knots	Ъ										0.2	24		23.68		
				0.0018	y	0.5 n			Falaillies from head on collision only Speed assumed to be >=8 knots	]b										0.2	24		23.88		
			1,0 Y	head on	<u>1</u>				Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from nudging fenders only	Ъ										02	24	6 34E-07	23.88	8 34E-D7	2 88
F	0 02 y		,	nudge 0.67					Speed assumed to be >=8 knots Falaillies from glancing fenders only	ď															l
1352			0.05	ninor gland	·e			7.77E-07	Speed assumed to be >=8 knots Severe glancing impact onto structure	-															ļ
			n			0.5	0.3		Speed assumed to be 4 knots Pipeline ruptures (NG or WO)	a	1	16		0.25	20.85					0.2	24		89,73		
007386					1	у у	9 0,7		Fatalities from let pool fire & collision Fatalities from head on collision only Speed assumed to be >=8 knots	Ь										02	24		23.88		
ļ				0.0018	у	0.5			Fatables from head on collision only Speed assumed to be >=8 knots	ь										0.2	24		23.88		
			0,95	head on	<u>1</u>	•		3.22E-09	Fatalties from head on collision only Speed assumed to be >=8 knots	ь										0.2	24	7.69E-08	23.88	7 69E-08	3.22
			y	0.33 nudge			[	5.95E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
ļ	[	0.0028 y		0.67 Inor glanc	<u></u>		[		Fatalities from glancing fenders only Speed assumed to be >=8 knots	ď															
L	89.0	1	0.05 n						Severe glancing impact onto structure Speed assumed to be 4 knots	e															1
	L	0,9974 n	•		w				Boat passes under bridge	ľ														i	
			Outcomes			Che		2.66E-08 7.4DE-04 cool		—	<del>.</del>	, , , , , , , , , , , , , , , , , , , ,				<del></del>							Total PLL	7 115-07	L

Natural gas / Oil pipeline Head en collision > 8 knots Nudging collision > 8 knots Glancing collision > 8 knots

Severe glanding impact onto structure, LOP Straight through

amend be Second by Second

Event tree for passage through Fremantie Bridge

Boat Name: <u>Vessel 8</u> Code V6 DO1 D

Design Option 1 Addition of delphins and fender strengthening

People exposed on boat

Downstream	n of bridg	e, travelik	t esti mori ga	sapona								People	exposed o	n bridge			Immediate								
Events												nces Bridge		Conseque	nces Boat										
3	2	3	4	5	6	7	8	. 9	10	11	Fal2ily	13	14	F-1500	16	17	18	19	20	18	19	20	21	22	23
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Sirikas bridga	Causes Structura I failure	Pipeline	anilion.	Frequency	Oulcome		Rate from pool and jet fice exposure on bridge	No. of	PLL	Rate from pool and jet fire exposure on boat	No. o <sup>a</sup> falailles	PLL	Boat Collision Glancing Fatality Rate	No. of	PLL	Boat Collision Head On Fatality Rale	No. of	PLL	Total No.	Total PLL	Freq
												16			119.4			119.4			119	~			
				0.0018	У	1 y	0.3 y 0.7 ft		Pipeline ruptures (NG or WO) Fatalities from let pool fire & collision Fatalities from head on collision only Speed assumed to be >= 8 knots Fatalities from head on collision only Speed assumed to be >= 8 knots	a b	1	16		0.5	59.7					0.2 0.2 0.2	24 24 24		99.58 23.88 23.88	•	
	0.004		1.0 y	head on 0.33 nudge	<u>1</u>				Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from nudging fenders only Speed assumed to be >=8 knots	ь										02	24	1 21E-07	23.88	1.21E-07	5.086-09
1352	y		0.05	0.67 ninor glant					Fatalities from glanding fenders only Speed assumed to be >=8 knots Severe glanding impact onto structure Speed assumed to be 4 knots	d •															
							0.3 y		Pipaline ruptures (NG or WO) Fatalities from jet pool fire & collision	•	1	16		0.5	59.7					0.2	24		UV 58		
0.0007396						у [	0.7 n		Fatalities from head on collision only Speed assumed to be >=8 knots	Þ										0,2	24		23 88		
- 1				0.0018 head on	,	n		3 205.00	Fatalilies from head on collision only Speed assumed to be >=8 knots Fataliles from head on collision only	ľ				ĺ						0.2	24		23 88		
		0.0026	y 95	0.33 nudge 0.67	an .			6.05E-07	Speed assumed to be >=8 knots Fatalities from nudging fenders only Speed assumed to be >=8 knots Fatalities from plancing fenders only	c										0.2	24	7.82E-08	23.48	7.82E-08	3.286-09
Į	1.00 n	У	D.05	ninor gland	e			9.58E-08	Speed assumed to be >=8 knots Severe glancing impact onto structure Speed assumed to be 4 knots															1	
	(	0.9974 n					$\dashv$	5.06E-09	Boat passes under bridge	]															
			Outcomes			Che	ck sum	7.40E-04	4		-			·									Total PLL	1.99E-07	

Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe giancing impact onto structure, LOP

Straight through

The state of the s

Event tree for passage through Fremantie Bridge

Boat Name : <u>Vessel 6</u>
Code V8 DO2 UP

Design Option 2 Widening of navigation spans

People exposed on boat

inum	n di	a١

				People	exposed a	u puage			immediale								
verks			Conseque	nces Bridge	5	Conseque	nces Boat										
1 2 3 4 5 6 7	8 9 10	1	1 F-12(tv	13	14	F-15.1v	18	17	18	19	20	18	19	20	21	22	23
Strikes Strikes al Strikes al Strikes Strikes speed Causes Gas/Oil Nav Non Nav greater than Strikes Structura Pipekins Frequency Span span 4 knots bridge I falker frugstyre li	nition Frequency Outcome		Rate from pool and jet fire exposure on bridge	No, of	PLL	Rate from pool and jet fire exposure on boat	No. o*	PLL	Boat Collision Glancing Fatality Rate	No. of	PLL	Boat Collision Head On Fatality Rale	No. of		Total No.		
Total   Total	and traded to the same		I all ellege	16	766	CITOCAL	119.4	1	Na(c	119.4	PLL	i Kale	119	PLL	of fatalities	Total PLL	Freq
0.5 y  0.6018 y  0.5 n  1.0 y  0.33 n  y  0.67 minor glance  0.05	0.3 Pipeline ruptures (NG or WO)  y Falatiles from let nool fire & colis 0.7 Falatiles from head on colision o Speed assumed to be >=8 knots 2.40E-09 Falatiles from head on colision o Speed assumed to be >=8 knots 4.44E-07 Falatiles from head on colision o Speed assumed to be >=8 knots 4.44E-07 Falatiles from rudging lenders on Speed assumed to be >=8 knots 8.88E-07 Falatiles from glancing lenders on Speed assumed to be >=8 knots 7.03E-08 Severe glancing impact onto struc	only bonly bonly bonly bonly c	1	16		0.25	29.86			119.4		0.2 0.2 0.2 0.2	118 24 24 24 24	5 74E-08	69.73 23.86 23.86 23.86	5.74E-08	2.40E-09
0.007396  0.0018  0.0018  0.0018  0.0018  0.0018  0.0018  0.0008  0.00	Speed assumed to be 4 knots Pipekine ruptures (NG or WO) Patalities from let.pool fite & colis Patalities from let.pool fite & colis Speed assumed to be >=8 knots Fatalities from head on colision or Speed assumed to be >=8 knots 1.09E-09 Fatalities from head on colision or Speed assumed to be >=8 knots Patalities from head on colision or Speed assumed to be >=8 knots 2.02E-07 Fatalities from head on colision or Speed assumed to be >=8 knots 4.04E-07 Fatalities from pading fenders or Speed assumed to be >=8 knots 3.20E-08 Severe glancing fenders or Speed assumed to be >=8 knots 3.20E-08 Severe glancing impact onto struct Speed assumed to be >=8 knots 3.20E-08 Boat passes under bridge 2.40E-09 T.40E-09 7.40E-09	niy b niy b niy c niy d	1	16	Mark Control	0.25	29.85				294	0.2 0.2 0.2 0.2	24 24 24 24 24	2.61E-09	59 73 23.88 23.88 23.88	281E-08	1 00E-D9

Natural gas / Oil pipeline Head on colison > 8 knots Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure, LOP Straight through

Boat Name : Vessel 6
Code V8 DO2 D
Design Option 2 Widening of navigation spans

People exposed on boat

Downstream	s of bridg	je, traveži	ng from the h	narbour	•							People	exposed o	n bridge			immediate	,	•						
Evants											Conseque	nces Bridge		Conseque	nces Boat										
11	2	3	4	5	6	7	8	9	10	11	F-1214	13	14	F-15/4v	16	17	18	19	20	18	19	20	21	22	23
Frequency	Skrikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots			Pipelin	•	Frequency	Oulcome		Rate from pool and jet fire exposure on bridge	No. of falalilies	PLL	Rate from pool and jet fire exposure on boat	No. of falaities	PLL	Boat Collision Glancing Fatality Rate	No. of fatakiles	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No.	Total PLL	Freq
						<del>- 1</del> -	0,3 y 0_7 n		Pipeäne ruptures (NG or WO) Fatalities from Jet pool fire & colision Fatalities from head on collision only Speed assumed to be >=8 knots Fatalities from head on collision only	a b	1	16		0.5	59.7					0.2	24 24		99.58		
[	0.602 y		10 y	0.0018 fread on 0.33 rudge 0.67	1 n	<u> </u>		4.448-07	Speed assumed to be >≃8 knots Fallsities from head on collision only Speed assumed to be >≈8 knots Fatalities from mudging fenders only Speed assumed to be >=8 knots Fatalities from plancing fenders only Fatalities from glancing fenders only	- u										02	24 24	5 74E-08	23.88 23.88	5.746-08	2 40E-09
1332 0.0007398			0.00	oning yan		1 y	9 0.7		Speed assumed to be >= 8 knots  Vavore uterology impant with structure  type of Assumed by the A birds  Pipaline ruptures (NG or WO)  Fatesities from let, pool fire & collision  Fatesities from head on collision only  Speed assumed to be >= 8 knots		ı	ld		<b>U</b> ,5	5 <b>0</b> /					u 2 0.2	24 24		23.86 nn pa		- ANALYS
			0.95 y	0,0018 head on 0.33		n		1,09E-09 2,02E-07	Fatakles from head on collision only Speed assumed to be >=8 knots Fatakles from head on collision only Speed assumed to be >=8 knots Fatakles from rudging fenders only	b b										0.2 0.2	24 24	2 81E-08	23.88 23.88	2.61E-08	1 09E-09
	1.00 ກ	0 0009 y 0.9991	0.05	nudge 0.67 minor gland	ie .			4.04E-07 3.20E-08	Speed assumed to be >=8 knots Fatalities from glanding fenders only Speed assumed to be >=8 knots Severe glanding impact onto structure Speed assumed to be 4 knots	d															
		n	Outcomes		·	CI	neck sum	2.40E-09 7.40E-04	Boat passes under bridge	<u>'</u>	***	a	•										Total PLL	8.35E-08	Ĺ

Natural gas / Oil pipeline Head on collison > 8 knots

Nudging collision > 8 knots Glancing collision > 8 knots

Severe glancing impact onto structure. LOP

Straight through

#### Summary Results of Event Trees for Design Options 1 & 2

Dezign Op	ilon 1																							Design Option 1
	001 UP	VII	DO1 D	V2 I	OOI UP	V2 1	DO1 D	V3 D	OI UP	V3 D	Q 101	V4 [	001 UP	V4	DOI D	V5 [	OOI UP	V3	DO1 D	VAN	101 UP	V61	Q 100	FN Date
No. of Faultice 202 106 106 106	Frequency 8.12E-08	No. of Palalities 282 106 106 106	Frequency 1.55E-08	No. of Futultiles 11: 42 42 42 42	Frequency 9.21E-08	No. of Falalities 163 42 42 42	Frequency	No. of Fatalities 117 45 45 45	Frequency 9.21E-08	No. of Familities 174 45 45 45	Frequency	No. of Fatalilien 132 66 66 66	Frequency	No. of Fatalities 182 66 66 66	Frequency 8.77E-09	No. of		No. of		No. of Faulities 70 24 24 24	Frequency 2.66E-08	No. of Fundities 190 24 24 24		
202 106 106 106	1,48E-09 3,45E-09 4,92E-09	282 106 106 106	3.91E-09 7.01E-09	111 42 42 42 42	1.67E-09 3.91E-09 5.58E-09	163 42 42 42	3.41E-09 7.95E-09	117 45 45 45	1.67E-09 3.91E-09 5.58E-09	174 45 45 45	3.41E-09 7.93E-09	(32 66 66 66	8.37E-10 1.95E-09 2.79E-09	182 66 66 66	1.70E-09 3.97E-09	80 28 28 28 28	5,58B-09	115 28 28 28 28	5.68E-09	70 24 24 24	3.22E-09	100 24 24 24 24	3.28E-09	111
No. of far Total PLL for even		No. of fat	3.93E-06	No. of fist	4.60E-06	No. of fat	2 18E-06	No. of fel	Freq 4.9312-06	No. of fat	2.32E-06	No. of fat	Freg 3.54E-06	No. of fat	Freq 1.41E-06	No. of fat	Freq 1.47E-06	No. of fal	Freq 4.10E-07	No. offul	7.11E-07	No. of fal	1 99E-07	
Dealgn Opt	lon 2																							Seun Total PLL
VI D No. of	O2 UP	Vi D No. of	O2 D	V2 D Na. of	02 UP	V2 D No. of	002 D	V3 DC No. of	)2 UP	V3 D No. of	D2 D	V4 D No. of	O2 UP		002 D		02 UP		DO2 D	V6 D	02 UP	V6 1:	102 D	Design Option 2 FN Data
Faulities 202 106 106 106	Frequency 7.35E-09	Fatalities 282 106 106 106	Frequency 7.35E-09		Frequency:	Fatalities 163 42 42 42 42	Frequency		Frequency 8.33E-09		Frequency: 8.33E-09	Falalities 132 66 66 66	Frequency	No. of Fatalities 182 66 66	Frequency 4.17E-09	No. of Fatelities 80 28 28	Frequency	No. of Fatalities 185 28 28 28	Frequency 4.17E-09	No. of Fatalities 70 24 24 24	Frequency 2.40E-09	100 24 24	Frequency	N P Processory 181 1.00E-09 1.00E-09 201 1.07E-09 2.07E-09 174 1.14E-09 3.21E-09
202 106 106	5.02E-10 1.17E-09 1.67E-09	781 106 106	1,00E-09 2,34E-09	111 42 42	5.69E-10 1.33E-09 1.90E-09	163 42 42	1.14E-09 2.65E-09	117 45 45	5.69E-10 1.33E-09 1.90E-09	174 45 45	1.14E-09 2.65E-09	t32 66 66	2.84F-10 6.64E-10 9.48E-10	192 66 66	5.69E-10 1.33E-09	80 28 28		21.5 28 28		70 24	2.40E-09	24 100 24	2 40E-09	163 1.14E-09 4.33E-09 132 2.84E-10 4.64E-09 117 3.69E-10 3.20E-09 111 3.69E-10 5.77E-09 106 1.99E-08 2.57E-08 66 1.13E-08 3.65E-08
106		106	_	42		42		45		45		66		66		28	1.90E-09	28	1.90E-09	24 24	1.09E-09	24 24	1 09E-09	45 2.23E.08 5.93E.08 42 2.23E.08 8.20E.08 28 1.21E.08 9.41E.08 24 6.99E.09 1.01E.07 1.01E.07

												1.01E-07	
No. of fat Freq Total FIL for even 1,24E-06	No. of fat Freq	No. of fel Freq	No. of fad Freq	No. of fat Freq	No. of fat Freq	No. of fal Freq	No. of fat Freq	No. of fat Freq	No. of fa Freq	No. of ful Freq	No. offst Freq	1.01E-07	check
1000 FIA: 101 EVEN 1:540-90	1.34E-06	6.00E-07	8.30E-07	6.41E-07	8.87E-07	4.44E-D7	5.54E-07		1,72E-07	8.35E-08	\$.35E-08	7 25E-06	

### Summary Frequency Results of Event Trees for Design Options 1 & 2

	Design Opti	ion 1													
Frequency of	1 DO1 U V	/1 DO1 D	2 DO1 U	V2 DO1 D	3 DO1 U	V3 DO1 D	4 DO1 U	V4 DO1 D	5 DO1 U	V5 DO1 D	6 DO1 U	V6 DO1 D			sign option 1 ency of Collision
Fatalities from jet,pool fire & collision														Nav span collision	·····
Fatalities from head on collision only														Head on	4.6.E-07
Fatalities from head on collision only														Glance	2.7.E-04
Fatalities from head on collision only		1.55E-08	9,21E-08	1.75E-08	9.21E-08	1.75E-08	4.60E-08	8.77E-09	4.60E-08	8.77E-09	2.66E-08	5.06E-09	4.6,E-07	Non nav span collision	
Fatalities from nudging fenders only	1.50E-05 2	2.86E-06	1.70E-05	3.24E-06	1.70E-05	3,24E-06	8.51E-06	1.62E-06	8.51E-06	1.62E-06	4.91E-06	9.35E-07	8.5.E-05	Head on	9.4.E-08
Fatalities from glancing fenders only	3.00E-05 5	5.72E-06	3.40E-05	6.48E-06	3.40E-05	6.48E-06	1.70E-05	3.24E-06	1.70E-05	3.24E-06	9.82E-06	1.87E-06	1.7.E-04	Glance	5.5.E-05
Severe glancing impact onto structure	2.38E-06 4	4.52E-07	2.69E-06	5.13E-07	2.69E-06	5.13E-07	1.35E-06	2.56E-07	1,35E-06	2.56E-07	7.77E-07	1.48E-07	1.3.E-05	Pass through	2.1.E-02
Fatalities from jel,pool fire & collision	1.48E-09 3	3.01E-09	1.67E-09	3.41E-09	1.67E-09	3.41E-09	8,37E-10	1.70E-09					1.7.E-08		2.1.E-02
Fatalities from head on collision only	3.45E-09	7.01E-09	3.91E-09	7.95E-09	3.91E-09	7.95E-09	1.95E-09	3.97E-09					4.0.E-08	check	1
Fatalities from head on collision only	4.92E-09		5.58E-09		5.58E-09		2.79E-09						1.9.E-08		•
Fatalities from head on collision only									5.58E-09	5.68E-09	3.22E-09	3.28E-09	1.8.E-08		
Fatalities from nudging fenders only	1.82E-06 1	1.85E-06	2,06E-06	2.10E-06	2.06E-06	2.10E-06	1.03E-06	1.05E-06	1.03E-06	1.05೬-06	5.95E-07	6.05E-07	1.7.E-05		
Fatalities from glancing fenders only	3.64E-06 3	3.70E-06	4.13E-06	4.20E-06	4.13E-06	4.20E-06	2,06E-06	2.10E-06	2.06E-06	2.10E-06	1.19E-06	1.21E-06	3.5.E-05		
Severe glancing impact onto structure	2.88E-07 2	2.93E-07	3.26E-07	3.32E-07	3.26E-07	3.32E-07	1.63E-07	1.66E-07	1,63E-07	1.66E-07	9.41E-08	9.58E-08	2.7.E-06		
Boat passos under bridge	2.21E-03 2	2.25E-03	2,50E-03	2.55E-03	2.50E-03	2.55E-03	1.25E-03	1.27E-03	1,25E-03	1.27E-03	7.22E-04	7.35E-04	2.1.E-02		
	2.26E-03 2	2.26E-03	2.56E-03	2.56E-03	2,56E-03	2.56E-03	1.28E-03	1,28E-03	1.28E-03	1.28E-03	7.40E-04	7.40E-04	2.1.E-02		
	Design Optio													De	sign option 2
Frequency of	_ 1 DO2 U V	/1 DO2 D	2 DO2 U	V2 DO2 D	3 DO2 U	V3 DO2 D	4 DO2 U	V4 DO2 D	5 DO2 U	V5 DO2 D	6 DO2 U	V6 DO2 D			ency of Collision
Fatalities from jet pool fire & collision	_													Nav span collision	one) or oursion
Fatalities from head on collision only														Head on	6.9.F-08
Fatalities from head on collision only		•													4.1.E-05
Fatalities from head on collision only		7,35E-09	8.33E-09	8.33E-09	8,33E-09	8.33E-09	4.17E-09	4.17E-09	4.17E-09	4.17E-09	2.40E-09	2.40E-09	6.9.E-08	Non nav span collision	,2 50
Falalities from nudging fenders only		1.36E-06	1.54E-06	1.54E-06	1.54E-06	1.54E-06	7.70E-07	7.70E-07	7.70E-07	7.70E-07	4.44E-07	4.44E-07	1.3.E-05	Head on	3.2.E-08
Fatalities from glancing fenders only		2.72E-06	3.08E-06	3.08E-06	3.08E-06	3.08E-06	1.54E-06	1.54E-06	1,54E-08	1.54E-06	8.88E-07	8.88E-07	2.6.E-05		1.8.E-05
Severe glancing impact onto structure		2.15E-07	2.44E-07	2.44E-07	2.44E-07	2.44E-07	1.22E-07	1.22E-07	1.22E-07	1.22E-07	7.03E-08	7.03E-08	2.0.E-06	Pass through	2.1.E-02
Fatalities from jet,pool fire & collision		1.00E-09	5.69E-10	1.14E-09	5.69E-10	1.14E-09	2.84E-10	5.69E-10					5.8,E-09		2.1.E-02
Fatalities from head on collision only		2.34E-09	1.33E-09	2.65E-09	1.33E-09	2.65E-09	6.64E-10	1.33E-09					1.3.E-08	check	1
Fatalities from head on collision only	1.67E-09		1.90E-09		1.90E-09		9.48E-10						6.4.E-09		•
Fatalities from head on collision only									1.90E-09	1.90E-09	1.09E-09	1.09E-09	6.0.E-09		
Fatalities from nudging fenders only		5.19E-07	7.01E-07	7.01E-07	7.01E-07	7.01E-07	3.51E-07	3.51E-07	3.51E-07	3.51E-07	2.02E-07	2.02E-07	5.8.E-06		
Fatalities from glancing fenders only			1.40E-06	1.40E-06	1.40E-06		7.01E-07	7.01E-07	7.01E-07	7.01E-07	4.04E-07	4.04E-07	1,2.E-05		
Severe glancing impact onto structure			1.11E-07	1.11E-07	1.11E-07	1.11E-07	5.55E-08	5.55E-08	5.55E-08	5.55E-08	3.20E-08	3.20E-08	9.3.E-07		
Boat passes under bridge	2.26E-03 2	2.26E-03	2.56E-03	2.56E-03	2,56E-03	2.56E-03	1,28E-03	1.28E-03	1.28E-03	1.28E-03	7.38E-04	7.38E-04	2.1.E-02		
	2.26E-03 2	2.26E-03	2.56E-03	2.56E-03	2.56E-03	2.56E-03	1.28E-03	1.28E-03	1.28E-03	1.28E-03	7.40E-04		2.1.E-02		



# Appendix 3

**Event Trees for Sensitivity** 

### Design Options Sensitivity Input Data

DO1 Strengthening Nav Spans clongating them by 5.5m
DO2 Widening of Nav spans
Diff between Sen and calc

				V2 :	slightly smaller	boat							
	VI	370	tonnes		V2	270	tonnes		V3	190	tonnes		V4
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream
Tree Data	I VI DOI UP	VIDOID	VI DO2 UP	V1 DO2 D	V2 DOI UP	V2 DO1 D	V2 DO2 UP	V2 DO2 D	V3 DOI UP	V3 DOLD	V3 DO2 UP	V3 DO2 D	V4 DOI UP
Frequency	2 2.26E-03	2.26E-03	2.261-03	2,26E-03	2,56B-03	2,56B-03	2.56E-03	2.56E-03	2.56E-03	2.56E-03	2.56E-03	2.56E-03	1,28E-03
No. of people exposed on b		800	800	800	525	525	525	525	450	450	450	450	400
No. of people exposed on b			16	16	16	16	16	16	16	16	16	16	16
Strikes Nav Span	5 0.021		0.0019	0.0019	0.021	0.004	0.0019	0.0019	0.021	0.004	0.0019	0.0019	0.021
	6 0.003		0.0009	0.0009	0.003	0.003	0,0009	0.0009	0.003	0.003	0.0009	0.0009	0.003
Strikes at speed greater tha	7 0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0,95	0.95	0.95	0,95
Strikes at speed greater tha	8 0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Strikes Head on	90.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	8100,0	0.0018	0.0018	0.0018	0.0018
Glances	0,93		0.33	0.33	0.33	0.33	0.33	0.33	0.33	0,33	0.33	0.33	0.33
Causes Structural failure N	# 28 1 2	1	1	1	1	1	1	1	1	1	1	1	1
Causes Structural failure N		0	0	0	0	0	0	a	0	0	0	0	0
	II 🐣 0.5	j	0.5	L	0.5	1	0,5	1	0.5	1	0,5	1	0,5
	11 3	0,3	0.3	0,3	0,3	0.3	0,3	0.3	0.1	0, 3	0.3	0.3	0.3
Bridge fatality rate from po			1	1	1	ı	1	1	1	1	1	1	1
Boat fatality rate from jet &	#	0.53	0.25	0,5	0.25	0.5	0.25	0.5	0.25	S 0.5	0.25	0.5	0.25
Boat fatality rate glancing c			0	0	0	0	0	0	0	0	0	0	0
Boat fatality rate sinking/de	// 0.33 ····	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33

to the state of th

## **Design Options Sensitivity Input Data**

									Boats smaller			
		155	tonnes		V5	115	tonnes		V6	45	tonnes	
	Ш	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Tree Data	11	V4 DO1 D	V4 DO2 UP	V4 DO2 D	V5 DOI UP	V5 DOLD	V5 DO2 UP	V5 DO2 D	V6 DOI UP	V6 DOLD	V6 DO2 UP	V6 DO2 D
Frequency	2	1.28E-03	1.28E-03	1.28E-03	1.28E-03	1.28E-03	1.28E-03	1,28E-03	7.40E-04	7.40E-04	7.40E-04	7.40E-04
No. of people exposed on		400	400	400	284	284	284	284	199	199	199	199
No. of people exposed on	4	16	16	16	16	16	16	16	16	16	16	16
Strikes Nav Span	5	0.004	0.0019	0.0019	0.021	0.004	0.0019	0.0019	0.021	0.004	0.0019	0.0019
Strikes Non Nav Span	6	0.003	0.0009	0.0009	0.003	0.003	0.0009	0.0009	0.003	0.003	0.0009	0.0009
Strikes at speed greater th	7	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.0003	0.0009
Strikes at speed greater th	8	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Strikes Head on	9	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	
Glances	#	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.0018	8100.0
Causes Structural failure	#	l	1	1	. 0	0	0	0	0.5.7	0.33	0.33	0.33
Causes Structural failure	#	0	0	0	0	0	0	0	0	<del></del>	0	0
Gas/oil pipeline failure	#	ı	0.5	1	0,5	1	0.5	1	0.5		0.5	0
Ignition	#	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3		
Bridge fatality rate from p	#	1	ı	The state of the s		1	1	1	1	1	0,3	0.3
Boat fatality rate from jet	# 4	0.5	0.25	\$ 0,5 €	0.25	0.5	0.25	0.5	0.25	2.5500 es 38	1	l
Boat fatality rate glancing	#	0	0	0	0	0	0.23	0	0.23	0.5		0,5
Boat fatality rate sinking/d		0.33	0,33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0	0
							0,00	<u></u>	0.33	0.33	0.33	0.33

Event tree for passage through Fremantie Bridge Boat Name : <u>Vessel 1</u> Code V1 DO1 UP

Design Option 1 Addition of dolphins and fender strengthening Upstream of bridge, travelling into the harbour

People exposed on boat

Immediate

ople exposed	on bridge	
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1	opsueam	or or tag	ie, navei	ing into th	e natoor								Реорје	exposeu	on priage			immediate	•							
Strikes Strike	Events													ridge	Consequ	iences Bo	at									
Strikes Strike	1	2	3	4	5	6	7_	8	9	10	11	F-12::-	13	14	- 15	16	17	18	19	20	18	19	20	21	22	23
10	Frequenc y	Nav	Non Nav	speed greater than 4	Strikes	Structu ral	ilPipeli ne ruptur	Ignitio				Rate from pool and jet fire	No. of	PLL	Rate from pool and jet fire	No. of	PI	Collision Glancing Fatality		PN	Collision Head On Fatality			of		Eron
0.5   Y   Fatalities from lead on collision of Speed assumed to be >=8 knots			<u> </u>					• • • •				10		, , , , , ,	- DAPOGGIQ			, rate		1_00	1 itale		T FLL	ialailles	I FLL	FIEG
0.3   1.48E-09   Pipeline ruptures (NG or WO)   5   1.48E-09   Pipeline ruptures (NG or WO)   5   1.48E-09   Pipeline ruptures (NG or WO)   5   1.48E-09   Pipeline ruptures (NG or WO)   5   5   7   7   7   7   7   7   7   7	442			y 0,05	0.33 nudge 0.67	1 n	y 0.5	9 0,7	8.12E-08 1.50E-05 3.00E-05	Fatalities from jet pool fire & collis Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Severe glancing impact onto struc	b b b	1			0.25				800		0.33 0.33	264 264 264	2.14E-05	264 264	2.14E-05	8.12 <b>E</b> -08
0.0018	0.002262							y 0.7		Pipeline ruptures (NG or WO) Fatalities from jet, pool fire & collisi Fatalities from head on collision o	a ion b	1	16	5.51E-08	0.25	200	6.89E-07	,								
0.0018						ÿ	0.5			Fatalities from head on collision o	ь										0.33	264	1.30E-06	264	1.30F-06	4 92F.09
0.95					0.0018 head on		ก			Speed assumed to be >=8 knots Fatalities from head on collision o	Ь										0.33					4.022-00
Intal PEL 2 ARE 05		0.98 n	y 0.9974 n	0.95 y m 0.05	0,33 nudge 0.67		Chec		1.82E-06 3.64E-06 2.88E-07 2.21E-03 8.47E-08	Speed assumed to be >=8 knots Fatafities from nudging fenders on Speed assumed to be >=8 knots Fatafities from glancing fenders o Speed assumed to be >=8 knots Severe glancing impact onto struc- Speed assumed to be 4 knots	c d	- 100									U.33	204				
				Quicomes			Chec	x sum	2.26E-03														7	Total PLL	2,48E-05	

Natural gas / Oil pipeline
Head on collison > 8 knots
Nudging collision > 8 knots
Glancing collision > 8 knots
Severe glancing impact onto structure, LOP

Straight through

Boat Name: Vessel 1 Code V1 DO1 D

Design Option 1 Addition of dolphins and fender strengthening

Downstream of bridge, travelling from the harbour

People exposed on bridge

The second secon

People exposed on boat

Immediate

			-								. oppi	exposed	on onage			immediate	7							
vents					·						uences B	ridge	Consequ	ences Bo	oat									
1	2	3	4	5	6	7	8	9	10	11 Fala	13	14	Faldity-	15	17	18	19	20	18	19	20	21	22	23
equenc	Strikes Nav	Strikes Non Nav	Strikes at speed greater than 4	Strikes	Structu ral			Frequenc		Rate from pool ar jet fire	ď		Rate from pool and jet fire	No. of		Boat Collision Glancing Fatality	No. af		Boat Collision Head On Fatality	No. of		Total No.		
<u> Y</u>	Span	span	knots	bridge	failure	e	n	y	Outcome		e fatalities	PLL	exposure		PLL		fatalities	PLL		fatalities	PLL	of fatalities		E.,
							0.3		Pipeline ruptures (NG or WO)	a 1	16 16		0.5	800 400			800			800	<u>, rec</u>		<u>                                    </u>	Fre
						1 y	у 0.7		Fatalities from jet pool fire & collision o	n.	10		0.5	400					0.33 0.33	264 264		680 264		
				0.0018	у	<u> </u>	n		Speed assumed to be >=8 knots Fatalities from head on collision o	b									0.33	264		264		
		_	1.0	head on	1 n	n		1.55E-08	Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots										0.33	264	4 09E-06	264	4.09E-06	1.5
٢	0.00 y		У	0.33 nudge 0,67			ľ	2.86E-06 5.72E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o															
142		Ĺ	0.05 n	ninor glan	ce	<del></del>	L	4.52E-07	Speed assumed to be >=8 knots Severe glancing impact onto struc Speed assumed to be 4 knots	ė														
2262					1		y		Pipeline ruptures (NG or WO) Fatalities from jet, pool fire & collisio Fatalities from head on collision o	л .	16	1.12E-07	0.5	400	2 81E-06				0.33	264	7 93E-07	680	3.71E-08	30
					1 y	у <u>Г</u>	n		Speed assumed to be >=8 knots Fatalities from head on collision o										0.33		1.85E-06		1.85E-06	7.0
				0.0018 head on		n			Speed assumed to be >=8 knots Fatalities from head on collision o										0.33	264 264		264		
		ſ	0.95 y	0.33	n			1.85E-06	Speed assumed to be >=8 knots Fatalities from nudging fenders on o	;									0.55	204		264		
	٦	0.0026 y	m	nudge 0.67 Inor gland	e	···		3.70E-06	Speed assumed to be >=8 knots Fatalities from glancing fenders o c Speed assumed to be >=8 knots	l														
L	1.00 n	· [	0.05 n			···	٦.	2.93E-07	Severe glancing impact onto struc a Speed assumed to be 4 knots	•														
	L	0.9974 n						2.25E-03	3oat passes under bridge															
		(	Dutcomes			Chack	أعسرة	2.26E-03	_		···												1	

Natural gas / Oil pipeline

Head on collision > 8 knots Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure, LOP Straight through

Boat Name: Vessel 1

Code V1 DO2 UP

Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

People exposed on bridge

People exposed on boat

Immediate

Second Second	- pourcum	4, 2,149	-, 11	and and m		••							. oopio	expessed t	on binage			miniculati	•							
Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   No. of present   present	Events											Consequ	ences Br	idge	Consequ	ences Bo	at									
Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   No. of present   present	11	2	3	4	5	6	7	8	9	10	111	- 12	13	14	- 15	16	17	18	19	20	18	19	20	21	22	23
Pipeline ruptures (NG or WO)   1	Frequenc y	Nav	Non Nav	speed greater than 4	Strikes	Structu ral	ilPîpeli ne ruptur		Frequenc y			Rate from pool and jet fire	fatalities	PLL	Rate from pool and jet fire	fatalities	PLL	Collision Glancing Fatality	fatalities	PLL	Collision Head On Fatality	fatalities		of	Total	Freq
10   10   10   10   10   10   10   10													10		1	600			600			000				
10							0.5					•	16		0.25	200					0.33	264		480		
Speed assumed to be >=8 knots							У	0.7			b										0.33	264		264		
1.00	•				0,0018						ь										0.33	264		264		
9.00					]		<del></del>	***************************************		Speed assumed to be >=8 knots											0.33	264	1.94E-06	264	1.94E-06	7.35E-09
442   0,05   Case					nudge 0 67	ice .			Ì	Speed assumed to be >=8 knots Fetalities from glancing fenders o	1														•	
0.002252    0.002252	442			0.05						Severe glancing impact onto struc Speed assumed to be 4 knots	ļ															
1								у		Fatalities from jet pool fire & collis	on	1	16	1.87E-08	0.25	200	2.34E-07	1								
0.0018	0.002262					1	y		1.17E-09		þ				l						0.33	264	3 09E-07	264	3.09E-07	1.17E-09
head on					D 0018				1.67E-09	Fatalities from head on collision o	b										0,33	264	4.42E-07	264	4.42E-07	1.67E-09
y 0.33   6.19E-07   Fatalities from nudging fenders on Speed assumed to be >=8 knots				0.05		l				Fatalities from head on collision o	ь										0.33	264		264		
0,0009						n 				Fatalities from nudging fenders or	ç															
1.00 0.05 9.79E-08 Severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed to be 4 knots of the severe glancing impact onto struc e Speed assumed in the severe glancing impact onto struc e Speed assumed in the severe glancing impact onto struc e Speed assumed in the severe glancing impact onto struc e Speed assumed in the severe glancing impact onto struc e Speed assumed in the severe glancing impact onto struc e Speed assumed in the severe glancing impact onto struc e Speed assumed in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the severe glancing in the sever			0,0009						1.24E-06		-															
0.9991 Speed assumed to be 4 knots 2.26E-03 Boat passes under bridge  8.52E-09		1.00	у		tinor glan	ce					l <sub>e</sub>				]											
8.52E-09			0.0004		714.797					Speed assumed to be 4 knots																
		į								Boat passes under bridge	ľ				!											
				Outcomes			Chec	k sum							<u> </u>				••••					Total Dt 1	3.085.09	

cool

Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure, LOP

Straight through

Boat Name \* Vessel 1 Code V1 DO2 D

Design Option 2 Widening of navigation spans

Downstream of bridge, travelling from the harbour

People exposed on boat Immediate

English Market M

People exposed on bridge Events Consequences Bridge Consequences Boat 2 1Ω 13 14 15 17 18 19 20 18 19 20 21 22 23 Strikes at Gas/O Rate Rate Boat Boat speed Strikes Causes il Pipeli from from Collision Collision Strikes Non greater Structu ne pool and pool and Glancina Head On Total No. Frequenc Nav Nav than 4 Strikes ral ruptur Itanitio Frequenc Fatality iet fire No. of iet fire No. of No. of Fatality No. of of Total bridge Span knots failure 'n exposure fatalities PLL exposure fatalties Rate fatalities PLL Rate fatalities fatalities Pil Freo 800 Pipeline ruptures (NG or WO) 16 0.5 400 0.33 264 680 Fatalities from jet, pool fire & collision 0.7 Fatalities from head on collision of h 0.33 264 264 Speed assumed to be >=8 knots Fatalities from head on collision of b 0.33 284 284 0.0018 Speed assumed to be >=8 knots head on 7.35E-09 Fatalities from head on collision o b 0.33 264 1 94E-06 264 1.94E-06 7 35E-09 Speed assumed to be >=8 knots 1.36E-06 Fatalities from nudging fenders on c 0.33 0.00 nudge Speed assumed to be >=8 knots 0.67 2.72E-06 Fatalities from glancing fenders o d minor glance Speed assumed to be >=8 knots 442 Severe glancino impact onto struc e Speed assumed to be 4 knots 1.00E-09 Pipeline ruptures (NG or WO) 3.75€-08 400 9 37E-07 0.33 264 2 65E-07 1.24E-06 1.00E-09 У Fatalities from jet pool fire & collision 0.002262 0.7 2.34E-09 Fatalities from head on collision o b 0.33 264 6.18E-D7 264 6.18E-07 2.34E-09 Speed assumed to be >=8 knots Fatalities from head on collision o b 0.33 264 264 0.0018 Speed assumed to be >=8 knots head or Fatalities from head on collision o b 0.33 264 264 Speed assumed to be >=8 knots 0.33 6.19E-07 Fatalities from nudging fenders on c nudge Speed assumed to be >=8 knots 0.0009 0.67 1.24E-06 Fatalities from glancing fenders o minor glance Speed assumed to be >=8 knots 1.00 9.79E-08 Severe glancing impact onto struc e Speed assumed to be 4 knots 2.26E-03 Boat passes under bridge 0.9991 9.69E-09

Natural das / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure, LOP

Check sum 2.26E-03

Straight through

Outcomes

Total PLL 3.80F-06

Boat Name: Vessel 2

Code V2 DO1 UP
Design Option 1

Addition of dolphins and fender strengthening Upstream of bridge, travelling into the harbour

People exposed on bridge

minimal of the contro

People exposed on boat

Immediate

1 2 3 4 5 6 7 8 9 10 11 Feldity 13 14 Feldity 15 17 18 19 20 18 19 20 21 22 23  Strikes at Strikes speed Strikes non greater Structu ne Frequenc Nav Nav than 4 Strikes rai ruptur Ignitio Frequenc Nav Nav than 4 Strikes rai ruptur Ignitio Frequenc	vents										C	Consequ	ences Bri	ldge	Consequ	ences Boa	at									
Strikes   Stri	1	2	3	4	5	6	7	8	9	10	11	E-12:	13	14	_ 15	16	17	18	19	20	18	19	20	21	22	23
0.5   y   Falalities from		Nav	Non Nav	speed greater than 4		Structu ral	ilPipeli ne ruptur					Rate from pool and jet fire	fatalities	PLL	Rate from pool and jet fire	fatalities	PLL	Collision Glancing Fatality	fatalities	PLL	Collision Head On Fatality	fatalities	PLL	of		Freq
1.0   1.0							a.e. 1				ļa	1	16		0.25	131,25					0.33	173		320.5		
0.0018								0.7		Fatalities from head on collision o											0.33	173		173 25		
1.0					0.0018	у		<u>",</u>		Fatalities from head on collision o	ь										0.33	173		173.25		
Speed assumed to be 4 knots   Speed assumed to be 4 knots   Speed assumed to be 5 knots	300			y	nead on 0.33 nudge 0.67	1			1 70E-05 3 40E-05	Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glanding fenders o Speed assumed to be >=8 knots	d										0.33	173	1.60E-05	173.25	1.60E-05	9.21E
0.0018	030									Speed assumed to be 4 knots Pipeline ruptures (NG or WO)	a	1	16	6.25E-08	0.25	131 25	5.13E-07				0.33	173	2 90E-07	320.5	8.65E-07	1.67E
0.0018	002564					1				Fatalities from head on collision o											0.33	173	6 77E-07	173.25	6.77E-07	3.916
head on									5.58E-09	Fatalities from head on collision o	ь										0.33	173	9.67E-07	173.25	9.67E-07	5.58E
nudge Speed assumed to be >=8 knots 0.0026				0.95	head on	ī	n			Fatalities from head on collision o Speed assumed to be >=8 knots											0.33	173		173.25		
0.98 0.05 3.26E-07 Severe glancing impact onto struc e  n n Speed assumed to be 4 knots		1			nudge 0.67				4.13E-06	Speed assumed to be >=8 knots Fatalities from glancing fenders o																
	ĺ	n	-	0.05	inor gian		<u></u>		3.26E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
9.60E-08				Outcomes			Chec		2.56E-03 cool															Total PLL	1.85E-05	,

Naturat gas / Oli pipeline
Head on collison > 8 knots
Nudging collision > 8 knots
Glancing collision > 8 knots
Severe glancing impact onto structure. LOP

Straight through

Boat Name : Vessel 2

Code V2 DO1 D

Design Option 1 Addition of dolphins and fender strengthening

Downstream of bridge, travelling from the harbour

People exposed on bridge

The second by th

People exposed on boat

Immediate

Domisticalii oi bituge, ita	Tenning no	un the ua	noui						Ped	ibie ext	posed o	on bridge			Immediati	•							
Events	,		·						equences	Bridg	e	Consequ	ences Bo	oat									
1 2 3	4	5	6	7	8	9	10	11 Fall	11	3	14	Fatality	16	17	18	19	20	18	19	20	21	22	23
Strikes Strikes Strikes Non Frequenc Nav Nav	greater than 4	Strikes	Causes Structu ral	ne ruptur		Frequenc		Ra fro pool jet f	e n and re No.			Rate from pool and jet fire	No, of		Boat Collision Glancing Fatality	No. of		Boat Collision Head On Fatality	No. of		Total No.		
y Span span	knots	bridge	failure	<u>e</u>	กุ	у	Outcome	expos	ure fatali	ies	PLL	exposure		PLL	Rate	fatalities	PLL		fatalities	PLL	fatalities		Fre
0.00 Y	1.0 y	0.0018 head on 0.33 nudge 0.67	n	1 y		3.24E-06 6.48E-06	Pipeline ruptures (NG or WO) Fatalities from jet, pool fire & collision Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders of	on o	16			0.5	525 262.5			525		0.33 0.33 0.33 0.33	525 173 173 173 173	3 04E-06	451.75 173.25 173.25	3.04E-06	
390 002564	0.05	0.0018	1 Y	i γ [	0.3 y	5.13E-07 3.41E-09 7.95E-09	Speed assumed to be >=8 knots Severe glancing impact onto struct Speed assumed to be 4 knots Pipefine ruptures (NG or WO) Fatalities from jet,pool fire & collision Fatalities from head on collision of Speed assumed to be >=8 knots Speed assumed to be >=8 knots	a 1 n	1€	1.2	27E-07	0.5	262 5	2 09≌-06				0.33 0.33 0.33	173 173 173	5.90E-07 1.38E-06		2.80E-08	l
0.0026 1.00 0.9974	0.95 y n 0.05	0.33 nudge 0.67 ninor gland	ń			2.10E-06 4.20E-06 3.32E-07	Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on C Speed assumed to be >=8 knots Fatalities from glancing fenders of Speed assumed to be >=8 knots Severe glancing impact onto structory of the se	; I										0,33	173		173.25		
	Outcomes			Check		2.55E-08 2.56E-03		<del></del>	·						11						Total PLL	7.22E-D6	· 

Natural gas / Oil pipeline Head on collison > 8 knots Nudging collision > 8 knots

Glancing collision > 8 knots Severe glancing impact onto structure, LOP

Straight through

Boat Name : Vessel 2 Code V2 DO2 UP

Widening of navigation spans Design Option 2

Upstream of bridge, travelling into the harbour

People exposed on bridge

Pro- Entertainment Control of Section Control of Se

People exposed on hoat

Immediate Events Consequences Bridge Consequences Boat 3 6 2 7 10 11 - 12 13 14 - 15. 16 17 18 19 20 18 18 20 21 22 23 Strikes at Gas/O Rate Rate Boat Boat Strikes Causes ilPipeli speed from from Collision Collision Strikes Non greater Structul ne Glancing bool and Head On nool and Total No. Frequenc May Nav than 4 Strikes rai ruptur Ignitio Frequen No. of Fatality jet fire jet fire No. of No. of Fatality No. of of Total Span span knots bridge failure e exposure fatalities exposure fatalities Rate fatalities PLL Rate fatalities PLL fatalities PLL Frea 525 Pipeline ruptures (NG or WO) 16 0.25 131.25 0.33 173 320.5 05 [ Fatalities from jet pool fire & collision 0.7 Fatalities from head on collision of h У 0.33173 173 25 Speed assumed to be >=8 knots 0.5 Fatalities from head on collision o b 0.33 173 173 25 0.0018 Speed assumed to be >=8 knots head on 8.33E-09 Fatalities from head on collision o 0.33 173 1 44E-06 173 25 1.44E-06 8.33E-09 Speed assumed to be >=8 knots 0.33 1 54E-06 Fatalities from nudging fenders on c 0.00 nudae Spend assumed to be >w8 knots 0.67 3.08E-06 Fatalities from glancing fenders o d Speed assumed to be >=8 knots minor glance 390 2.44E-07 Severe glancing impact onto struc e Speed assumed to be 4 knots 5.69E-10 Pipeline ruptures (NG or WO) 2.12E-08 0.25 131.25 1.74E-07 0.33 9.86E-08 320.5 2.94E-07.5.69E-10 Fatalities from jet pool fire & collision 0.5 У 0.002564 0.7 1,33E-09 Fatalities from head on collision olb y 0.33 2.30E-07 173.25 2.30E-07 1.33E-09 n Speed assumed to be >=8 knots 1.90E-09 Fatalities from head on collision of 0.33 173 3.29E-07 173.25 3.29E-07 1.90E-09 0.0018 Speed assumed to be >=8 knots head on Fatalities from head on collision o b 0.33 173 173.25 0.95 Speed assumed to be >=8 knots 7.01E-07 0.33 Fatalities from nudging fenders on c nudge Speed assumed to be >=8 knots 0.0009 0.67 1.40E-06 Fatalities from glancing fenders o minor glance Speed assumed to be >=8 knots Severe glancing impact onto struc e Speed assumed to be 4 knots 2.56E-03 Boat passes under bridge 0.9991

Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure. LOP

Check sum 2.56E-03

9.66E-09

Straight through

Outcomes

Total PLL 2.30E-08

Boat Name: Vessel 2 Code V2 DO2 D

Design Option 2 Widening of navigation spans

Downstream of bridge, travelling from the harbour

People exposed on boat

People exposed on bridge

be formed to for

DOMUZUE				in the ha	, DOU!							reopie	exposed o	m unage			Immediate	,							
Events		,										ences B	ridge	Consequ	ences B	oat									
1	2	3	4	5	6	7	8	9	10	11 ra	2	13	14	Falsility	18	17	18	19	20	18	19	20	21	22	23
Frequenc y	Strikes Nav Span	Strikes Non Nav span	Strikes a speed greater than 4 knots	Strikes bridge		ne ruptur	Ignitio n	Frequenc y		R: fro pool jet	ate om l and fire	No. of	PLL	Rate from pool and jet fire exposure	No. of	PLL	Boat Collision Glancing Fatality Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of	PLL	Total No of fatalities	Total	Fre
												16			525			525		1 1 1 1 1 1	525	,	Manager	, ,	1 ' ' '
						1 y	0.3 y 0.7		Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collisio Fatalities from head on collision o	n	1	16		0.5	262.5					0.33	173		451.75		
						] ′ ′	n		Speed assumed to be >=8 knots	,										0.33	173		173.25		
				0.0018 head on		n			Fatalities from head on collision o b Speed assumed to be >=8 knots											0.33	173		173.25		
390	0.00 y		1.0 y	0.33 nudge 0.67 ninor glan	n	75114		1.54E-06 3.08E-06 2.44E-07	Fatalities from head on collision o Speed assumed to be >=8 knots.  Fatalities from nudging fenders on Speed assumed to be >=8 knots.  Fatalities from glancing fenders o Speed assumed to be >=8 knots.  Severe glancing impact onto structed speed assumed to be 4 knots.	; I										0.33	173	1 44E-06	173.25	1.44E-06	8.33E
•						1 [	0.3 y	1.14E-09	Pipeline ruptures (NG or WO) a		1	16	4.25E-08	0.5	262.5	6.97E-07				0.33	173	1 97E-07	451.75	9.37E-07	1.148
0.002564					1	У	0.7	2.65E-09	Fatalities from head on collision o b Speed assumed to be >=8 knots	•										0.33	173	4 60E-07	173,25	4.60E-07	2.65€
				0.0018	<del>  ,</del>				Fatalities from head on collision o	•										0,33	173		173 25		
			0.95	head on		n			Speed assumed to be >=8 knots Fatalities from head on collision o											0.33	173		173 25		
	1.00 n	0.0009 y 0.9991	у	0.33 nudge 0.67 ninor gland	ce	Check		7.01E-07 1.40E-06 1.11E-07	Speed assumed to be >=8 knots Fatalities from nudging fenders on c Speed assumed to be >=8 knots Fatalities from glancing fenders o d Speed assumed to be >=8 knots Severe glancing impact onto struc e Speed assumed to be 4 knots Goat passes under bridge								1 10 10					·		2.84E-06	

Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots Glancing collision > 8 knots

Severe glancing impact onto structure. LOP Straight through

Boat Name: Vessel 3
Code V3 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening Upstream of bridge, travelling into the harbour

People evonged on hidde

A STATE OF THE PROPERTY OF THE

People exposed on boat

upstream	of bridg	je, trave	iling into tr	ie harboi	ır							People	e exposed	on bridge			Immediate	:							
Events			·	· · · · · · · · · · · · · · · · · · ·			,	,	<del>,</del>		Consequ	iences B	ridge	Consequ	iences Be	oat									
1_	2	3	4	5	6	7	8	9	10	11	Fallity	13	14	Feldity	16	17	18	19	20	18	19	20	21	22	23
Frequenc y	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge		ne ruptur	ŧ	Frequenc y			Rate from pool and jet fire exposure		s PLL	Rate from pool and jet fire exposure	No. of	; PLL	Boat Collision Glancing Fatality Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of	PLL	Total No of fatalities	Total	Freq
												16			450			450			450				
						0.5	0,3 y	<u> </u>	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collis		1	16		0.25	112.5					0.33	149		277		
						У	0.7 n	1	Fatalities from head on collision o Speed assumed to be >=8 knots	b				İ						0.33	149		148.5		ĺ
				0.0018	Y	0.5 n			Fatalities from head on collision o	Ь										0 33	149		148.5		
				head or					Speed assumed to be >=8 knots Fatalities from head on collision o	ь										0 33	149	1 37E-05	148.5	1.37E-05	9 215-08
			10 y	0 33	n			1 705-05	Speed assumed to be >=8 knots Fatalities from mudging fonders on													7 0.1 2 00	1	1.012.00	10212-00
	0.02		<b>.</b>	nudge					Speed assumed to be >=8 knots	ŀ															
	У		۱ ،	0.67 ninor glan	ice				Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
390			0.05					2.69E-06	Severe glancing impact onto struc	e															
			n				0.3	1.67E-09	Speed assumed to be 4 knots Pipeline ruptures (NG or WO)		1	16	6.25E-08	0.25	1126	4.39E-07	i			0.00	4.46				
0.002584						0.5	Гу	i. :	Fatalities from jet pool fire & collisi	ion ion	•	.0	0.250.00	0.23	1125	4.39E-07				0.33	149	2 49E-07	277	7.51E-07	1.67E-09
0.002304					. 1	y	0.7 n		Fatalities from head on collision o Speed assumed to be >=8 knots	b				1						0.33	149	5 80E-07	148.5	5.80E-07	3.91E-09
				0.0018	y	0.5		5.58E-09	Fatalities from head on collision o	ь										0.33	149	8,29E-07	148.5	8.29E-07	5.58E-09
				head on					Speed assumed to be >=8 knots Fatalities from head on collision o	ь										0.33	149		148.5		ļ
1			0,95 y	0.33	n				Speed assumed to be >=8 knots Fatalities from nudging fenders on											0.00	1-15		140.5		
- }			l '	nudge				2.002-00	Speed assumed to be >=8 knots	٦															
		0.0026	1	0.67				4.13E-06	Fatalities from glancing fenders o	d				1											
		У		inor glan	ce			1 1	Speed assumed to be >=8 knots	l				•											
l	0.98		0.05					3.26E-07	Severe glancing impact onto struc	θ															
	n	0.9974	n						Speed assumed to be 4 knots													,			
	ι	0.9974 N						2.005-03	Boat passes under bridge	1															
		••						9.60E-08		J				l											
			Outcomes			Chec	k sum	2.56E-03			-			L	~~~								L	1.505.55	
								cool														_	rotal PLL	1.58E-05	

Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure. LOP Straight through

Boat Name: Vessel 3
Code V3 DO1 D
Design Option 1 A

Addition of dolphins and fender strengthening Downstream of bridge, travelling from the harbour

People exposed on bridge

the first of the f

People exposed on boat

Immediate

Events								,		,	Consequ			Consequ	ences Bo		· · ·			,		·	,		
1	2	3	4	5	6	7	8	9	10	11	Foldity	13	14	Falsity	16	17	18	19	20	18	19	20	21	22	23
Frequenc y	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Structu	ruptur		Frequenc Y	Outcome		Rate from pool and jet fire	No. of fatalities	PLL	Rate from pool and jet lire exposure	No. of fatalities 450	PLL	Boat Collision Glancing Fatality Rate	No. of fatalities 450	PLL	Boat Collision Head On Fatality Rate	No of fatalities	PLL	Total No of fatalities	Total	Freq
						4 1	0.3	<u> </u>	Pipeline ruptures (NG or WO) Fatalities from jet pool fire & colli	a	1	16		0.5	225					0.33	149		389.5		
					У	у 0.7 л	ļ	Fatalities from head on collision of Speed assumed to be >=8 knots											0.33	149		148.5			
				0.0018	У	<u> </u>			Fatalities from head on collision of Speed assumed to be >=8 knots	┚										0.33	149		148.5		
ſ	0.00		1,0 Y	0.33 nudge	1 n			3,24E-06	Fatalities from head on collision to Speed assumed to be >= 8 knots Fatalities from nudging fenders o Speed assumed to be >= 8 knots	nc										0.33	149	2 60E-06	148 5	2.60E-06	1,75E-
390	У		0.05 n	0,67 ninor glan	ce			5.13E-07	Fatalities from glancing fenders of Speed assumed to be >= 8 knots Severe glancing impact onto strue Speed assumed to be 4 knots	1		40	4 000 00			4 705 0									
.002564						1 Y	0.3 y 0.7		Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collis Fatalities from head on collision of		1	16	1.27E-07	0,5	225	1.79E-0	5			0.33 0.33	149 149	5.06E-07		2 42E-06	
				0.0018	1 y		n		Speed assumed to be >=8 knots Fatalities from head on collision of Speed assumed to be >=8 knots	-										0.33	149	:	148.5		
			0.95	head on					Fatalities from head on collision of Speed assumed to be >=8 knots	]										0.33	149		148.5		
		0.0026	y	0.33 rudge 0.67					Fatalities from nudging fenders of Speed assumed to be >=8 knots Fatalities from glancing fenders of Fatalities from nudging fenders of Fatalities from nudging fenders of Fatalities from nudging fenders of Fatalities from nudging fenders of Fatalities from nudging fenders of Fatalities from nudging fenders of Fatalities from glancing fenders of Fatalities from glancing fenders of Fatalities from glancing fenders of Fatalities from glancing fenders of Fatalities from glancing fenders of Fatalities from glancing fenders of Fatalities from glancing fenders of Fatalities from glancing fenders of Fatalities from glancing fenders of Fatalities from fenders of Fatalities fr	J															
	1.00	У	0.05	ninor glan	ce			3.32E-07	Speed assumed to be >=8 knots Severe glancing impact onto struct Speed assumed to be 4 knots	e															
	n	0.9974 n	n			<del> </del>	<del></del>	2.55€-03	Boat passes under bridge	ſ															
			Outcomes	;		Chec	k sum	2,55E-08 2,56E-03	···· ·		····									***************************************			Total Di f	6 21E-06	

Natural gas / Oil pipeline

Natural 945 / Oir pipeline
Head on collision > 8 knots
Nudging collision > 8 knots
Glancing collision > 8 knots
Severe glancing impact onto structure. LOP

Straight through

Event tree for passage through Fremantie Bridge Boat Name : <u>Vesset 3</u> Code V3 DO2 UP

Widening of navigation spans

Design Option 2 Wildening of navigati
Upstream of bridge, traveiling into the harbour

People exposed on bridge

People exposed on boat

e	1mmed

			_									ldge	1	· 1		1			1.5		- ^ -		- 6	1 -
2	3	4	5	6	7	88	9	10	11 F	-12ity	13	14	Falfia	15	17	18	19	20	18	19	20		- 22	2
Strikes Nav	Strikes Non Nav	Strikes at speed greater than 4	Strikes	Structu	ne ruptur	Ignitio	Frequenc		po	Rate from ool and et fire	No. of		Rate from pool and jet fire	No. of	51.1	Glancing Fatality	No. of	mr.	Boat Collision Head On Fatality	No. of	011	Total No.	Total	F
Span	span	knots	bridge	failure	e	_n_	у	Oulcome	ex	posure		PLL	exposure		PLL	Rate		PLL	Rate		PLL	fatalities	PLL	╁
					0.5 y	0.3 y 0.7		Fatalities from jet, pool fire & collisi Fatalities from head on collision o	on	1	16		0.25	112.5			450		0.33 0.33	149 149		277 148.5		
			0.0018		0.5 n	л		Fatalities from head on collision o Speed assumed to be >=8 knots											0.33	149		148.5		
0.00 y		0.05	0.33 nudge 0.67	n			1 54E-08 3.08E-06 2.44E-07	Speed assumed to be >=8 knots Fatalities from hudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Severe glancing impact onto struc	c d										0 33	149	1 24E-06	146.5	1 24E-08	8
		n			0.5	у	5.69E-10	Pipetine ruptures (NG or WO) Fatalities from jet,pool fire & collis		1	16	2.12E-08	0.25	12.5	1.49E-07				0.33	149			2.55E-07	ı
				1	y	0.7 n		Speed assumed to be >=8 knots	1															ı
					0.5 n		L	Speed assumed to be >=8 knots	1												2,826-07		2.82E-07	T
1.00 n	0.0009 y 0.9991		0.33 nudge 0.67	n			7.01E-07 1.40E-08 1.11E-07 2.56E-03	Speed assumed to be >= 8 knots Fatalities from nudging fenders on Speed assumed to be >= 8 knots Fatalities from glancing fenders o Speed assumed to be >= 8 knots Severe glancing impact onto struc Speed assumed to be 4 knots	G G										0.33	149		148.5		
		0.4			01-								l									Total DL1	1 075 08	ᆚ
	Strikes Nav Span	Strikes Nav Span  0.000  y  0.0009  1.00  n  0.9991	Strikes at speed greater than 4 knots  10 0.00  y  0.00  y  0.000  y  0.000  y  0.000  n  0.000  n  0.000  n  0.000  n  0.000  n  0.000  n	Strikes   Strikes at speed   Strikes   Strikes   Strikes   Speed   S	Strikes Strikes at speed greater Nav Span span span span span span span span s	Strikes Strikes at speed	Strikes Strikes at speed greater than 4 span span span span span span span span	Strikes Non Nav Span   Strikes at Speed greater Ihan 4 Span   Strikes honds   Strikes at Span   Strikes   Strikes at Span   Strikes   St	Strikes Non Non Speed speed I han 4 Strikes at Span   Strikes I han 4 Span   Strikes I han	Strikes speed speed respond to be >=8 knots of speed assumed to be	Strikes Non Now greater Strikes at Speed greater Non Now Speed assumed to be >=8 knots Not Speed assumed to be >=8 knots Not Speed assumed to be >=8 knots Not Survey No. Not Speed assumed to be >=8 knots Not Speed assumed to be A knots Not Speed assumed to be A knots Not Speed assumed to be A knots Not Speed assumed to be A knots Not Speed assumed to be A knots Not Speed assumed to be A knots Not Speed assumed to be A knots Not Speed assumed to be A knots Not Speed assumed to B	Strikes Non Nav Speed Strikes at Speed (Causes) (Gas/O) (Causes) (Firem pool and jet firempool and jet firempool and jet firempool and jet firempool and jet firempool and jet firempool and jet firempool and jet firempool and jet firempool and jet firempool and jet firempool and	Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Strikes   Tail   Tuptur   In   In   In   In   In   In   In   I	Strikes   Str	Strikes   Strikes   Speed   Causes   Hippell   Imple	Strikes   Strikes   Speed   Causes	Strikes   Strikes   Speed   Structu   Strikes   Speed   Speed assumed to be >=8 knots   Spee	Strikes   Strikes   Speed   Speed   Speed   Strikes   Speed   Strikes   Speed   Strikes   Speed   Strikes   Speed   Strikes   Speed   Strikes   Strikes   Speed   Strikes   Strikes   Speed   Strikes   Stri	Stilkes   Stilkes   Speed   Causes   Filippel   Struct	Stilkes   Stil	Strikes   Stri	Strikes   Stri	Strikes   Stri	Strike   S

- a Natural gas / Oil pipeline
- b Head on collison > 8 knots

- c Nudging collision > 8 knots
  d Glancing collision > 8 knots
  e Severe glancing impact onto structure. LOP
- f Straight through

Event tree for passage through Fremantie Bridge Boat Name : <u>Vessel 3</u> Code V3 DO2 D

Widening of navigation spans Design Option 2

Downstream of bridge, travelling from the harbour

People exposed on boat

People exposed on bridge

**I**mmediate

more personnel framework f

1 2 3 3 4 5 0 7 8 9 10 11   Falling   13 14   Falling   15 17   18 9 20 18   19 20 22   22   22   23   Shikes at Shikes at Shikes at Shikes at Shikes at Shikes at Shikes at Shikes at Shikes   14   15   15   17   18   19 20 18   19 20 22   22   22   22   23   24   25   24   24   24   24   24   24	JOH DAG CO	2111 01 01	iage, iiu	ivening noi	iii uie iiai	Dou							· copic	exhosen.	ou puage			miniewate	•							
Strikes strikes strikes at Strike	Events													ridge	Consequ	Jences Bo	at									
Strikes   Stri	1	2	3	4	5	6	7	8	9	10	11	-12:	13	14	- 15	16	17	18	19	20	18	19	20	21	22	23
1		Nav	Non Nav	speed greater than 4	Strikes	Structu	ilPipeli ne ruptur	Ignitio	Frequenc			Rate from pool and jet fire	No. of	. PI1	Rate from pool and jet fire	No. of	PH	Collision Glancing Fatality		ρι)	Collision Head On Fatality			of .		Freq
1   1   1   1   1   1   1   1   1   1		Opan	_ open	I MIDES	, bitage	1 randic			l	Todoone	ш	CXPOSUIC		<u> </u>	CAPOSOIC		1 64	I TRACC			1 Nate		1	iataitties		TIES
0.0009				0.05	0.33 nudge 0.67 ninor glan	n n n n n n n n n n n n n n n n n n n	1 Y	0.3 y 0.7 n	8.33E-09 1.54E-06 3.08E-06 2.44E-07 1.14E-09 2.66E-09	Fatalities from jet pool fire & collis Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be ≥=8 knots Fatalities from head on collision o Speed assumed to be ≥=8 knots Fatalities from nudging fenders on Speed assumed to be ≥=8 knots Fatalities from glancing fenders o Speed assumed to be ≥=8 knots Fatalities from glancing fenders o Speed assumed to be ≥=8 knots Speed assumed to be 4 knots Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collision o Speed assumed to be ≥=8 knots Fatalities from head on collision o Speed assumed to be ≥=8 knots Fatalities from head on collision o Speed assumed to be ≥=8 knots Fatalities from head on collision o Speed assumed to be ≥=8 knots Fatalities from head on collision o Speed assumed to be ≥=8 knots Fatalities from head on collision o Speed assumed to be ≥=8 knots	on b b c d e a on b b	1	16	<b>4.25E-0</b> 8		225	5.97 <b>£</b> -07		450		0.33 0.33 0.33 0.33 0.33	149 149 149 149 149 149	1 69E-07	148.5 148.5 148.5 389.5 148.5	8.09E-07	1.14E-(
			y 0.9991 n	0.05 n	nudge 0.67 hinor glan	ce			1.40E-06 1.11E-07 2.56E-03 1.10E-08	Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Severe glancing impact onto struc Speed assumed to be 4 knots	d															
Outcomes Check sum 2.56E-03 Total PLL 2.44E-06				Outcomes			Chec				_	•	.,								<del></del>			Total PI !	2 445.08	

a Natural gas / Oil pipeline

a Natural gas / Oil pipeline
b Head on collison > 8 knots
c Nudging collision > 8 knots
d Glancing collision > 8 knots
e Severe glancing impact onto structure, LOP
f Straight through

Event tree for passage through Fremantle Bridge Boat Name : <u>Vessel 4</u>

Code V4 DO1 UP

Addition of dolphins and fender strengthening Design Option 1

Uostream of bridge, travelling into the harbour

People exposed on bridge

People exposed on boat

Immediate

1   2   3   4   5   6   7   8   9   10   11   Falility   13   14   Falility   13   14   Falility   15   16   17   18   19   20   18   19   20   21   22   23	Upstream	of bridg	e, trave	lling into th	e naroou	ır							Copie	exposed t	iii biidgo			minicoloso								
1	Events													ridge		ences Bo					<del>,</del>					
Strikes   Stri	1	2	3	4	5	6	7	8	9	10	11	Ea12:	13	14	Fa15	16	17	18	19	20	18	19	20	21	22	23
Part   Span		Nav	Non Nav	speed greater than 4	Strikes	Structu ral	ilPipeti ne ruptur l		Frequenc			Rate from poot and jet fire	No. of	PII	Rate from pool and jet fire		PLI.	Collision Glancing Fatality		PLL	Collision Head On Fatality	No. of		of		Freq
760  O.00182  O.0018	у	Span	span	Knots	i bridge	ianure	L_6L	- 11	У	Oblicome	-	exposure		11 144	Exposure		1 20	1 1446								
D Speed assumed to be 4 knots 1.25E-03 Boat passes under bridge t 4.80E-08	780 0.001282	У		0.05 °°°°°°°°°°°°°°°°°°°°°°°°°°°°°°°°°°°	0.33 nudge 0.67 inor glan 0.0018 head on 0.33 nudge 0.67	ace 1 y	0.5 0.5 7	9 0.7 n 0.3 y 0.7	8 511 00 1.70E-05 1.35E-06 8 37E-10 1.95E-09 2.79E-09 1.03E-06	Fatalities from jet, pool fire & collision of Speed assumed to be >=8 knots. Fatalities from head on collision of Speed assumed to be >=8 knots. Fatalities from head on collision of Speed assumed to be >=8 knots. Fatalities from head on collision of Speed assumed to be >=8 knots. Fatalities from mindjing fenders of Speed assumed to be >=8 knots. Fatalities from glancing fenders of Speed assumed to be >=8 knots. Severe glancing impact onto structures (NG or WO) Fatalities from jet, pool fire & collision of Speed assumed to be >=8 knots. Fatalities from head on collision of Speed assumed to be >=8 knots. Fatalities from head on collision of Speed assumed to be >=8 knots. Fatalities from head on collision of Speed assumed to be >=8 knots. Fatalities from head on collision of Speed assumed to be >=8 knots. Fatalities from nudging fenders of Speed assumed to be >=8 knots. Fatalities from glancing fenders of Speed assumed to be >=8 knots. Fatalities from glancing fenders of Speed assumed to be >=8 knots. Fatalities from glancing fenders of Speed assumed to be >=8 knots.	on de and de and	1	16	3,12€-08		160	1.95E-0	,	400		0.33 0.33 0.33 0.33 0.33	132 132 132 132 132 132	1 10E-07 2 58E-07	132 132 132 132 248 132	3.37E-07 2 58E-07	8 37E-10
4.80≅-08		л	0.9974						1,25E-03		- ,															
			n						L <u></u>		╛															
				0			Chaol				_				L									Total DI I	7.045.08	<u> </u>

Natural gas / Oil pipeline Head on collison > 8 knots

Nudging collision > 8 knots Glancing collision > 8 knots

Severe glancing impact onto structure, LOP

cool

Event tree for passage through Fremantle Bridge Boat Name : <u>Vessel 4</u> Code V4 DO1 D Design Option 1 Addition of dolphins an Addition of dolphins and fender strengthening

Downstream of bridge, travelling from the harbour

People exposed on bridge

The second of th

People exposed on boat

Immediate

DOMUSTLE	am or un	ioge, tra	veiling iro	m the na	Done							1 copic	cxposed (	ni bilage				="							
Events				_						.,	Consequ	ences B	idge		ences Bo		<b></b>	,			,	r			
1	2	3	4	5	6	7	8	9	10	111	Faldity	13	14	-Falality-	16	17	18	19	20	18	19	20	21	22	23
Frequenc y	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Structu	ruptur	lgnític n	Frequenc Y	Outcome		Rate from pool and jet fire exposure	No. of	: PLL	Rate from pool and jet fire exposure	No. of	PLL	Boat Collision Glancing Fatality Rate	No. of fatalities	. PLL	Boat Collision Head On Fatality Rate		PLL	Total No. of fatalities	Total	Freq
												•-											l		İ
						4 1	0.3 y		Pipeline ruptures (NG or WO) Fatalities from let pool fire & collin	]a sion	1	16		0.5	200					0.33	132		348		
						Ÿ	0,7		Fatalities from head on collision of Speed assumed to be >=8 knots											0.33	132		132		1
					У		n		Fatalities from head on collision of	5 b										0.33	132		132		
				0.0018 head or		ń		8.77E-09	Speed assumed to be >=8 knots Fatalities from head on collision of	,  -										0.33	132	1.16E-06	132	1.16E-06	8.77E+0
			1,0 Y	0.33	n			1.625.06	Speed assumed to be >=8 knots Fatalities from nudging fenders or					1											
	0.00		'	nudge				1.020.00	Speed assumed to be >=8 knots	" "															1
	у		1	0.67				3.24E-06	Fatalities from glancing fenders o	i a													1		
	'		l n	ninor glar	nce			1	Speed assumed to be >=8 knots	1													ĺ		
780			0,05					2.56E-07	Severe glancing impact onto struc	cle													1		l
- 20			n					1	Speed assumed to be 4 knots	1													}		ŀ
			••				0.3	1.70E-09	Pipeline ruptures (NG or WO)	Ta a	1	16	6.36E-08	0.5	200	7 95E-0	7			0.33	132	2 25E-07	348	1.08E-06	1.70E-0
						1 [	у ,	1	Fatalities from jet, pool fire & collis		•		•/												1117 41111 -
0,001282						ΓΫ́		3.97E-09	Fatalities from head on collision of											0.33	132	5.25E-07	132	5.25E-07	3.97E-0
					1	′ '	11	1	Speed assumed to be >=8 knots	T															
					У	Ĺ			Fatalities from head on collision of	ь										0.33	132		132		Ì
				0.0018		n			Speed assumed to be >=8 knots	┨.										0.00	422		400		
				head or	$\overline{}$				Fatalities from head on collision of	3 0										0.33	132		132		
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			у	0,33				1.05€-06	Fatalities from nudging fenders or	nje															
			ł	nudge					Speed assumed to be >=8 knots	┨.															
	١.	0.0026		0.67				2.10E-06	Fatalities from glancing fenders o	· la															1
		Y		ninor glar	ice				Speed assumed to be >=8 knots	4															}
	1.00		0.05					1.65E-07	Severe glancing impact onto struc	ole.															
	л		n						Speed assumed to be 4 knots	4.															1
	Į.	0.9974						1.2/E-03	Boat passes under bridge	ľ															1
		U						4 05 00	<u> </u>	J															1
								1.27E-08	1					<u> </u>									<u>L</u>		<u> </u>
			Outcomes	•		Chec	K SUM	1.28E-03	ľ														rotat PLL	2.77E-08	i

Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

e Severe glancing impact onto structure. LOP

f Straight through

Event tree for passage through Fremantle Bridge

Boat Name: Vessel 4
Code V4 DO2 UP
Design Option 2
Upstream of bridge, travellin

Widening of navigation spans

Paople exposed on hridge

to the second beautiful to the second be second by second by second by second by second by second by second by

People exposed on boat

lmr	edi	ate
44 1 11 1	:CU	O IC

Upstream	of bridge	e, travel	ling into th	e harbou	Г							People	exposed o	on bridge			Immediate								
Events												ences Br		Consequ		·	,								· · · · · · · · · · · · · · · · · · ·
1	2	3	4	5	6	7	88	9	10	11	Faldity	13	14	Falsity	16	17	18	19	20	18	19	20	21	22	23
Frequenc y	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structu ral failure	ne	Ignitio n	Frequenc y	Outcome		Rate from poot and jet fire	No. of fatalities	PLL	Rate from pool and jet fire exposure	No. of fatalities 4CO	PLL	Boat Collision Glancing Fatality Rate	No. of fatalities 400	PLL	Boat Collision Head On Fatality Rate	No. of fatalities 400	PLL	Total No. of fatalities	Total PLL	Freq
						or f	0.3		Pipeline ruptures (NG or WO)	٦a	1	16		0.25	100					0.33	132	!	248		
						0.5 y	y 0.7 n		Fatalities from jet,pool fire & collis Fatalities from head on collision o Speed assumed to be >=8 knots											0.33	132		132		
				0.0018	У	0.5 n			Fatalities from head on collision of Speed assumed to be >=8 knots	ь										0.33	132		132		
				head on	1 n				Fatalities from head on collision o Speed assumed to be >=8 knots	╛										0.33	132	5 50E-07	132	5.505-07	4.17E-09
	0 00		У	0.33 nudge					Fatalities from nudging fenders or Speed assumed to be >=8 knots	nc															
ı	<u> </u>		•	0 87			ŀ		Fatalities from glancing fonders o	1.															
	,		l n	nnor glan	CO				Speed assumed to be >=8 knots	1"															
780			0.05	· · · · · ·					Severe glancing impact onto struc	e															1 '
			n						Speed assumed to be 4 knots	1															
Ì						0.5			Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collis	ļa	1	16	1.06E-08	0.25	100	6.64E 08	3			0.33	132	3 75E-08	248	1 15E-07	2 84E-10
0.001282							9 0.7		Fatalities from head on collision o											0.33	132	6 76E-08	132	8 76E-08	8.64E-10
0.001202					1	' '	п		Speed assumed to be >=8 knots											0.00			'	-	
					У	0,5			Fatalities from head on collision o	ь										0.33	132	1.25E-07	132	1,25E-07	9.48E-10
				0.0018	ŀ	n	-		Speed assumed to be >=8 knots	┨、										2.00	400		400	i	
1			0.95	head on	ln				Fatalities from head on collision o Speed assumed to be >=8 knots	ייןי										0.33	132		132		i i
			<u> </u>	0.33	,,				Fatalities from nudging fenders or																
]			1 '	nudge	•				Speed assumed to be >=8 knots	1													İ		
	_	0.0009	j	0,67				7.01E-07	Fatalities from glancing fenders o	þ													Ì		
		У		inor glan	ce				Speed assumed to be >=8 knots	_				İ											1
Į	1.00		0.05						Severe glancing impact onto struc	e				1									1		
	п	0.9991	R				. 1		Speed assumed to be 4 knots  Boat passes under bridge	١.													1		
	L	n - 1866.0						1.202-03	noar hasses miner budge	'													Ī		
							•	4.83E-09	, , , , , , , , , , , , , , , , , , , ,																
			Outcomes			Check	k sum [	1.28E-03		_				·	,,						_	•	Total PLL	8.77E-07	

Natural gas / Oil pipeline
Head on collison > 8 knots
Nudging collision > 8 knots

Glancing collision > 8 knots
Severe glancing impact onto structure. LOP
Straight through

Event tree for passage through Fremantle Bridge Boat Name : <u>Vessel 4</u>

Code V4 DO2 D

Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

People exposed on bridge

to Second to Sec

People exposed on boat

Immediate

DOMISHE	all of Di	luge, na	Aciming ston	11 (110 110)	DOUL							. copio	capace 1	on binage			.,,								
Events											Consequ	ences Br	idge	Consequ	ences Bo	at									
1	2	3	4	5	6	7	8	9	10	11	-Fallity-	13	14	Falshity	16	17	18	19	20	18	19	20	21	22	23
Frequenc	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structu ral failure	ne		Frequenc			Rate from pool and jet fire exposure	No. of	PLL	Rate from pool and jet fire exposure	No. of	PLL	Boat Collision Glancing Fatality Rate	No. of	PL1.	Boat Collision Head On Fatality Rate	No. of	PLL	Total No. of fatalities	Total	Freq
<u> </u>	эран	Span	KIIOIS	1 bridge	1 lanule	1 6	- 41	<u>, y</u>	Joulcome		ехрозите	16	T	CYPOPRIE	400		I Ivere	400	FLL	1 Maic	400	<u> </u>	tataities	I FEL	TIEG
780	0.00 y		1.0 Y m 0.05	0.0018 head on 0.33 nudge 0.67 inor glan	n	1 y	0.3 y 0.7 n	4.17E-09 7.70E-07 1.54E-06 1.22E-07	Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collis Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be ≥=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots	b b c d	1	16		0.5	200			400		0.33 0.33 0.33 0.33	132 132 132 132	5.50 <b>⊆</b> -07	348 132 132 132	5 50E-07	4.17E-09
j			n				0.3		Speed assumed to be 4 knots Pipeline ruptures (NG or WO)	_	4	16	2.12E-08	0.5	200	2.65E-07	,			0.33	132	7 61 5 00	248	3.62E-07	E COE 10
0.001282	1.00 n	0.0009 y	0.95 Y	0.0018 head on 0.33 nudge 0.67 inor glan	n n cee	n	у 0.7 п	1.33E-09 3.51E-07 7.01E-07 5.55E-08	Piperine ruptures (NG or WO) Fatalities from let pool fire & collisi Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Severe glancing impact onto struc Speed assumed to be >=8 knots Beat passes under bridge	b b c d	1	16	2.12 <b>E-0</b> 8	0.5	200	2.00E-07				0.33 0.33 0.33	132 132 132 132	7 51E-08	132 132 132	3.62E-07	'
	·	n							eer, passes under onage	J.															
			Outcomes			Chec	k sum	5,49E-09 1,28E-03		_				l			<del>-</del>			<del></del>	<del></del>		Total PLL	1.09E-06	

a Natural gas / Oil pipeline

a harural gas / Oil pipeline
Head on collision > 8 knots
C Nudging collision > 8 knots
d Glancing collision > 8 knots
Severe glancing impact onto structure, LOP
f Straight through

Event trae for passage through Fremantie Bridge Boat Name : <u>Vessel 5</u> Code V5 DO1 UP Design Option 1 Addition of dolphins an Addition of dolphins and fender strengthening

People exposed on bridge

People exposed on boat

pstream	of bridge	e, travell	ing into th	e narbou	Г							i copic .	exposed o	ar Etiago			immediate								
vents									* ·		Consequ				ences Bo		<del></del>			<del></del>		1		22	23
1	2	3 Strikes	4 Strikes at speed		6 Causes	7 Gas/O ilPipeli	8	9	10	11	Falcility Rate from	13	14	Fatality Rate from	16	17	18 Boat Collision	19	20	18 Boat Collision	19	20	21		23
tedneuc	Strikes Nav	Non Nav	greater than 4	Strikes	Structu ral		Ignitio	Frequenc			pool and	No. of		pool and jet fire	No. of		Glancing Fatality	No. of	PLL	Head On Fatality Rate	No of fatalities	PLL	Total No. of (atalities	Total PLL	Fre
У	Span	span	knots	bridge	failure	e	n	<u> </u>	Outcome		exposure	fatalities 16	PLL	exposure	fatalices   284	PLL	Rate	fatalities 284	L_PLL	Rate	284	<u> PLL</u>	iatanties	FEL	FIE
							0.3		Pipeline ruptures (NG or WO)	la	1	16		0.25	71					0.33	94		180.72		
						0.5	У	1 1	Fatalities from jet pool fire & collis	ion	•	,													
						У	0.7		Fatalities from head on collision o	b										0.33	94		93.72		
					у	0.5	n		Speed assumed to be >=8 knots Fatalities from head on collision o	ь										0.33	94		93 72		
				0.0018		n			Speed assumed to be >=8 knots	١.										0 33	94	4.31E-06	03.72	4.31E-06	8 4 60
			1.0	head on	1 n				Fatalities from head on collision o Speed assumed to be >=8 knots	b				1						0.33	94	4.016-00	9372	4.512-00	1.00
		- 1	У	0.33				8 51F 06	Futulities from nudging fenders on	c				1											1
	0 02			nudge					Spond assumed to be >= 0 knots																
Ì	У			0.87 inor glan			_		Falulities from glancing fenders o Speed assumed to be >=8 knots	ľ															
780			0.05	mich Glan					Severe glancing impact onto struc	e				i											
		,	n						Speed assumed to be 4 knots	]															
- 1							03		Pipeline ruptures (NG or WO)	a	1	16		0.25	71					0.33	94		180.72		1
						0.5	y 0.7		Fatalities from jet pool fire & collis Fatalities from head on collision o											0.33	94		93.72		1
001282						γL	_ <u></u>		Speed assumed to be >=8 knots	١"										0.00	-		55.1.2		1
[					У	0.5			Fatalities from head on collision o	ь										0.33	94		93,72		
1				0.0018		n			Speed assumed to be >=8 knots	]													00.70	r 00m 07	-1
				head on					Fatalities from head on collision o	b										0.33	94	5 23E-07	93.72	5.23E-07	/10.0
1			0.95		n				Speed assumed to be >=8 knots Fatalities from nudging fenders on	1.				i											
			У	0,33 nudge					Speed assumed to be >=8 knots	16				1									i		
		0.0026		0,67					Fatalities from glancing fenders o	1,				ļ									l		1
	1	y y	D.	inor glan	re				Speed assumed to be >=8 knots	ľ															İ
1	0.98	, , l	0,05	mior grain	••				Severe glancing impact onto struc	le.															1
	n	'	0						Speed assumed to be 4 knots	ľ															
		0.9974	.,						Boat passes under bridge	٦f													1		
		n						1		1													1		1
								4.60E-08						l .											
			Outcomes			Chec	k eum	1.28E-03	1														Total Pt I	4.84E-06	6

Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots Glancing collision > 8 knots

Severe glancing impact onto structure. LOP

Event tree for passage through Fremantle Bridge

Boat Name: Vessel 5
Code V5 DO1 D

Design Option 1

Addition of dolphins and fender strengthening

Downstream of bridge, travelling from the harbour People exposed on bridge People exposed on boat

Immediate

<b>-</b>	vents         Consequence           1         2         3         4         5         6         7         8         9         10         11         Falcity														_										
		1 2		T =	٠	1 7			10			nces Bri	dge 14	Consequ	ences Boa	17	18	19	20	18	45				1
requenc Y	Strikes	Strikes Non Nav span	Strikes at speed greater than 4 knots	1	Causes Structu	Gas/O ilPipeli ne		Frequenc		F	Facility Rate from pool and jet fire exposure	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure	No of fatalities	PLL	Boat Collision Glancing Fatality	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of	20 PLL	21 Total No. of fatalities	22 Total PLL	Fre
												16		{	284			284			284				1
						_1_	0.3 y		Fatalities from jet, pool fire & collision		1	16		0.5	142					0.33	94		251.72		
					<del></del>		0.7 n		Fatalities from head on collision o Speed assumed to be >=8 knots											0.33	94		93.72		
				0.0018 head on	y 1	n		8 77E 00	Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o											0.33 0.33	94	2 205 23	93 72		<u> </u>
780	0.00 y		1.0 y 0.05	0.33 nudge 0.67 ninor gland	n			1.62E-06 3.24E-06 2.56E-07	Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Severe glancing impact onto struc Speed assumed to be 4 knots	c d										0.33	94	8 22E-07	93 72	8.22E-07	8.77
004000							0.3 y		Fatalities from jet pool fire & collision		1	16		0.5	142					0 33	94		251 72		
001282						y L	0.7 n		Fatalities from head on collision o	b										0.33	94		93 72		
				0.0018	Y				Fatalities from head on collision o	b										0.33	94		93.72		
7. 7. 7. 7. 7. 7. 7. 7. 7. 7. 7. 7. 7. 7	1.00 n	0.0026 y 0.9974	0.95 y 0.05 n	head on 0.33 nudge 0.67 inor gland	n			5.68E-09 1.05E-06 2.10E-06 1.66E-07	Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Severe glancing impact onto struct Speed assumed to be 4 knots Boat passes under bridge	c d										0.33	94	5 32E-07		5.32E-07	

La Company La Company

a Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure. LOP
Straight through

Event tree for passage through Fremantie Bridge

Boat Name: Vessel 5

Code V5 DO2 UP

Design Option 2 Widening of navigati Widening of navigation spans

People exposed on bridge

People exposed on boat

mm	

Upstream	of bridg	e, travel	ling into th	e narpou	ır							People	exposea (	on prage			mmediate	•							
Events												ences Bri			iences Bo					η		1			
1	2	3	4	5	6	7	8	9	10	11	Fallity	13	14	Feldity	16	17	18	19	20	18	19	20	21	22	23
Frequenc 	Strikes Nav Span	Strikes Non Nav Span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structu ral failure	ne ruptur		Frequenc			Rate from pool and jet fire		PLL	Rate from pool and jet fire exposure	No. of	PLL	Boat Colfision Glancing Fatality Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities		Total No. of fatalities	Total PLL	Freq
						0.5	0.3 y	<u> </u>	Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collis	a	1	16		0.25	71					0.33	94		180.72		
						y y	0.7 n		Fatalities from head on collision o Speed assumed to be >= 8 knots											0.33	94		93.72		
				0.0018	У	0.5 n			Fatalities from head on collision o Speed assumed to be >=8 knots	ь										0.33	94		93.72		
į	<u>0 00</u>	1140 <b>270</b> 2 /0-1	10 Y	head or 0.33 nudge 0.67	1 1			7 70(- 07	Fatalities from head on collision o Speed assumed to be >= 8 knots Fatalities from nudging fenders on Speed assumed to be >= 0 knots Fatalities from glancing lenders o Speed assumed to be >= 8 knots	c										0.33	94	3 90E-07	93.72	3 90E-07	4 17E-0
780 0.001282			0.05 n	- gran		0.5 y	0.3 Y 0.7	1.22E-07	Severe glancing impact onto struc Speed assumed to be 4 knots Pippline ruptures (NG or WO) Fatalities from jet, pool fire & collis Fatalities from head on collision o	a ion	1	16		0,25	71					0.33 0.33	94 94		180.72 93.72		
					У	0.5	n		Speed assumed to be >=8 knots Fatalities from head on collision o	ь										0.33	94		93.72		
		0.0000	0.95 y	0.0018 head or 0.33 nudge		n		3.51E-07	Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots	c										0.33	94	1.78E-07	93.72	1.78E-07	1.90E-0
ļ	1.00 n	0.0009 y 0.9991		0.67 ninor glar	nce			5.55E-08	Fatalities from glancing fenders o Speed assumed to be >=8 knots. Severe glancing impact onto struc Speed assumed to be 4 knots Boat passes under bridge					THE PLANT OF THE PARTY OF THE P							•				
			Outcomes	;		Chec	k sum	1.28E-03		_	-												Total PLL	5.68E-07	
								coot																	

a Natural gas / Oil pipeline
b Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots

Severe glancing impact onto structure. LOP

Event tree for passage through Fremantle Bridge Boat Name : Vessel 5

Code V5 DO2 D

Widening of navigation spans Design Option 2

Downstream of bridge, travelling from the harbour

People exposed on bridge

And the second terms to th

People exposed on boat

Immediate

		•	. •											3-											
Events		,	·	,			,	,				ences Bri	dge		ences Boa	at				·,·········					
1	2	3	4	5	6	7	8	9	10	11	ralaity	13	14	Fatality	15	17	18	19	20	18	19	20	21	22	23
Frequenc y	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structu ral failure	ne ruptur		Frequenc y			Rate from pool and jet fire exposure	No. of fatalities	PLL	Rate from pool and jet fire exposure	No. of	PLL	Boat Collision Glancing Fatality Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No. of fatalities	Total PLL	Freq
												16			284			284			284				
						1 Y	0.3 y 0.7		Fatalities from jet, pool fire & collisi Fatalities from head on collision o		1	16		0.5	142					0 33 0 33	94 94		251.72 93.72	٠	
					У	1	n		Speed assumed to be >=8 knots Fatalities from head on collision o	h.										0 33	94		93.72		
				0.0018	]	n			Speed assumed to be >=8 knots Fatalities from head on collision o											0.33	94	3.90E-07		2 00= 07	4.17E-09
780	0.00 y		1,0 y 0.05	0.33 nudge 0.67 ninor glan	n			7.70E-07 1.54E-06 1.22E-07	Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=6 knots Severe glancing impact onto struc Speed assumed to be 4 knots	d										0.33	94	3.90⊵-07	93.72	3.90⊵-07	4.176-09
							0.3		Pipeline ruptures (NG or WO)	a	1	16		0.5	162					0.33	94		251 72		
0.001282						<del> </del>	9 0.7 n		Fatalities from jet, pool fire & collisi Fatalities from head on collision o Speed assumed to be >=8 knots											0.33	94		93.72		
				0.0018	у	<u> </u>			Fatalities from head on collision o	ь										0.33	94	ì	93.72		[
	1.00 n	0.0009 y 0.9991	0.95 y m 0.05	0.0018 head on 0.33 nudge 0.67 hinor glan	n	n		1.90E-09 3.51E-07 7.01E-07 5.55E-08	Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Severe glancing impact onto struc Speed assumed to be 4 knots Boat passes under bridge	c										0.33	94	1 78E-07	93 72	1.78E-07	1.90E-09
			Outcomes			Chec		1.28E-03	·				<del></del>	L			-					<u>-</u>	Total PLL	5.68E-07	

Natural gas / Oil pipeline Head on collison > 8 knots

Nudging collision > 8 knots
Glancing collision > 8 knots
Severe glancing impact onto structure, LOP

Straight through

Event tree for passage through Fremantie Bridge

Boat Name: Vessel 6

Code V6 DO1 UP Design Option 1

Addition of dolphins and fender strengthening

Upstream of bridge, travelling into the harbour

People exposed on bridge

People exposed on boat

Immediate

vents				-		1 - 1					Consequ			A	ences Boa	17	45	- 10		1 40 1	40		~~~	22	23
1	2 Strikes	3 Strikes Non	Strikes at speed greater	5	6 Causes Structu	Gas/O ilPipeli ne	8_	9	10		Fatality Rate from pool and	13	14	Fatality Rate from pool and	15	1.7	18 Boat Collision Glancing	19	20	18 Boat Collision Head On	19 _	20	21 Total No.		23
requenc		Nav	than 4	Strikes	ral	ruptur	Ignitio	Frequenc			jet fire	No. of		jet fire	No. of		Fatality	No. of		Fatality	No. of		of	Total	
y	Span	span	knots	bridge	failure	e	n	y .	Outcome		exposure		PLL	exposure		PLL	Rate	fatalities	PLL	Rate	fatalities	PLL	fatalities	PLL	Fre
												16		1	199			199			199			- 1	
						0.5	0.3 y		Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collisi	a	1	16		0.25	49,75					0 33	66		131.42		
						y	0.7 n		Fatalities from head on collision o Speed assumed to be >=8 knots											0.33	66		65 67		
				0.0018	у	0.5 n			Fatalities from head on collision o Speed assumed to be >=8 knots											0.33	66		65.67		
			1.0	head on	1 n				Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on											0.33	66	1 74E-06	65.67	1.74E-06	2.66E
	0 02		у	nudge 0.67			•		Speed assumed to be >=8 knots Fatalities from glancing fenders o	ļ															
1352	y		ก 0.05	inor glan	ce				Speed assumed to be >=8 knots Severe glancing impact onto struc																
			n				0,3		Speed assumed to be 4 knots	a	1	16		0.25	49.75					0.33	66		131.42		
.00074						0.5 y	y 0.7		Fatalities from jet, pool fire & collisi Fatalities from head on collision o											0.33	66		85.67	į	
				1	у	0.5	n		Speed assumed to be >=8 knots Fatalities from head on collision o	b										0.33	66		65.67		
				0.0018 head on		n		3.22E-09	Speed assumed to be >≈8 knots Fatalities from head on collision o	b										0 33	66	2 11E-07	85 67	2 11E-07	3,22
			0,95 y	0.33	n			5.95E-07	Speed assumed to be >=8 knots Fatalities from nudging fenders on	С														ĺ	
	ſ	0.0026	_	nudge 0.67 inor gland				1.19E-06	Speed assumed to be >≈8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
Ì	0.98 n	y	0.05	шо уап				9.41E-08	Severe glancing impact onto struc Severe assumed to be 4 knots	e															
		0.9974 n							Boat passes under bridge	f															
		•	Outcomes			~		2.66E-08 7.40E-04		l				<u> </u>				****						1.96E-06	

Natural gas / Oil pipeline
Head on collison > 8 knots
Nudging collision > 8 knots
Glancing collision > 6 knots
Severe glancing impact onto structure. LOP

Event tree for passage through Fremantie Bridge

Boat Name: Vessel 6
Code V6 DO1 D
Design Option 1

Addition of dolphins and fender strengthening

Downstream of bridge, travelling from the harbour

People exposed on bridge

b Remark Paris Par

People exposed on boat

**Immediate** 

ents											Consequ	ences Bri	dne	Consequ	ences Boa	at									
1	2	3		5	6	7	8	9	10		Foldity	13	14		16	17	18	19	20	18	19	20	21	22	
quenc Y		Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structu	ne		Frequenc	Oulcame		Feldity Rate from pool and jet fire exposure	No. of fatalities	PLL	Fatelity Rate from pool and jet fire exposure	No. of fatalities	PLL	Boat Collision Glancing Fatality Rate	No. of	PLL	Boat Collision Head On Fatality Rate	No. of		Total No of fatalities	Total	F
												16		1	199			199			199				Ì
						1	0.3 Y		Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collisi	a	1	16		0.5	99 5					0.33	66		181.17		
						У	0.7		Fatalities from head on collision o Speed assumed to be >= 8 knots											0,33	66		65.67		
				0.0018		<u></u>			Fatalities from head on collision o Speed assumed to be >=8 knots	]										0.33	66		65.67		
	ø.00 y			0.33 nudge 0.67 inor glan	n			9.35E-07 1.87E-06	Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots	d										0.33	66	3 32E-07	65,67	3.32E-07	5.
52		l	0.05 n				0.3		Severe glancing impact onto struc Speed assumed to be 4 knots Pipeline ruptures (NG or WO)	a	1	16		0.5	99 5					0.33	66		181 17		
074						y	y 0.7		Fatalities from jet,pool fire & collisi Fatalities from head on collision o Speed assumed to be >=8 knots											0.33	66		65.67		
-				0.0018	У				Fatalities from head on collision o Speed assumed to be >=8 knots	ь										0.33	66		65 67		
		0.0026	0.95 y	head on 0.33 nudge 0.67				3.28E-09 6.05E-07	Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots	c										0 33	66	2.156-07	65 67	2 15∈-07	3.1
Į	1.00	y	0.05	inor glan	ce			9.58E-08	Fatalitles from glancing fenders o Speed assumed to be >=8 knols Severe glancing impact onto struc Speed assumed to be 4 knots	ı															
		0.9974 n	11.					7.35E-04	Boat passes under bridge	f															
			Outcomes			Chec		5.06E-09 7.40E-04																5.47E-07	L

a Natural gas / Oil pipeline
b Head on collison > 8 knots

Nudging collision > 8 knots Glancing collision > 8 knots

Severe glancing impact onto structure. LOP

Event tree for passage through Fremantle Bridge

Boat Name: Vessel 6
Code V6 DO2 UP

Design Option 2 Widening of navigation spans

Upstream of bridge, travelling into the harbour

People exposed on boat

People exposed on bridge	Immediate
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Events											Consequ	ences Bri	dge	Consequ	ences Bo	at									
11	2	3	4	5	6	7	8	9	10	11	Fatality	13	14	Fallity	15	17	18	19	20	18	19	20	21	22	23
Fraquenc	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structu ral failure	пе		Frequenc Y			Rate from pool and jet fire	No. of fatalities	PLL	Rate from pool and jet fire	No. of fatalities	PLL	Boat Collision Glancing Fatality Rate	No. of fatalities 199	PLL	Boat Collision Head On Fatality Rate	No of fatalities	PLL	Total No. of fatalities	Total	Freq
1352	0 00 y		1.0 y	0.0018 head on 0.33 nudge 0.67 linor glan	n	0.5 Y 0.5 n		4 44F 07 8 88E-07 7.03E-08	Fatalities from let pool fire & collisis Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots i utilities from head on collision o Speed assumed to be >=8 knots fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from glancling fenders o Speed assumed to be >=8 knots Severe glancing impact onto struc Speed assumed to he 4 knots	b b c d	1	16		0.25	49.75			195		0.33 0.33 0.33 0.33	66 66 66 66	1 58E-07	131.42 65 67 65 67 65 67	1 58E-07	2 40E-09
0.00074	1.00 n	0.0009 y 0.9991 n	0.95 y	0.0018 head on 0.33 nudge 0.67 inor gland	ก	0.5 y 0.5 n		1.09E-09 2.02E-07 4.04E-07 3.20E-08	Pipeline ruptures (NG or WO) Fatalities from Jet.pool fire & collisis Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from head on collision o Speed assumed to be >=8 knots Fatalities from nudging fenders on Speed assumed to be >=8 knots Fatalities from glancing fenders o Speed assumed to be >=8 knots Severe glancing impact onto struc Speed assumed to be 4 knots Boat passes under bridge	b b c d	1	16		0.25	49.75					0.33 0.33 0.33 0.33	66 66 66	7 18E-08	131 42 65.87 85.67 65 67		1.09E-09

Natural gas / Oil pipeline

b Head on collison > 8 knots
c Nudging collision > 8 knots
d Glancing collision > 8 knots

e Severe glancing impact onto structure. LOP straight through

Event treé for passage through Fremantie Bridge Boat Name : <u>Vessel 6</u> Code V6 DO2 D

Design Option 2 Widening of navigation spans Downstream of bridge, traveiling from the harbour

People exposed on bridge

The same of the sa

People exposed on boat

Immediate

	iii, Oi Di i	luge, ua	reiling fro	n me nai	DOUL								exposed (	•			Immediate	1							
ents 1	2	3	4	-		1 7 T	8	9	10	14		ences Bri	dge 14		ences Boa	17	·	4.5	20	1 40		T			1 -
•	Strikes	Strikes Nan	Strikes at speed greater		Causes Structu	Gas/O ilPipeli ne		_		1	Fatelity Rate from pool and		14	Fatality Rate from pool and			18 Boat Collision Glancing	19		18 Boat Collision Head On	19	20	21 Total No.		2
equenc	Nav	Nav	than 4	Strikes		ruptur 1		Frequenc	0.1		jet fire	No. of	<b>.</b>	jet fire	No. of		Fatality	No. of		Fatality	No. of		of	Total	
<u> Y</u>	Span	span	knots	bridge	failure	e	n	y	Outcome	ــــــــــــــــــــــــــــــــــــــ	Texposure	fatalities	PLL	exposure	199	PLL	Rate	fatalities 199	PLL	Rate	fatalities 199	PLL.	fatalities	PLL	F
												10			199			199			199		l		
						1 [	0.3 y		Pipeline ruptures (NG or WO) Fatalities from jet pool fire & collis	]a iion	1	16		0.5	99,5					0.33	66		181.17		
						УĹ	0.7 n		Fatalities from head on collision of Speed assumed to be >=8 knots	J										0.33	66		65.67		
				0.0018	У	์ ภ	[		Fatalities from head on collision of Speed assumed to be >=8 knots	]										0.33	66		65.67		
			1.0	head on	<u>1</u>				Fatalities from head on collision of Speed assumed to be >=8 knots	]										0.33	66	1.58E-07	65 67	1.58E-07	7 2.4
	0.00		y	0.33					Fatalities from nudging fenders or	١c															1
Г	V.00			nudge 0.67			}		Speed assumed to be >=8 knots Fatalities from glancing fenders o	۱,															
	,	i	r	inor glan	ce				Speed assumed to be >=8 knots	ľ															
52			0.05	mior gion.	••		İ		Severe glancing impact onto struc	le															
- 1			n				$\neg$		Speed assumed to be 4 knots														ŀ		
							0.3		Pipeline ruptures (NG or WO)	a	1	16		0.5	99.5					0 33	66		181.17		1
						1	Y .		Fatalities from jet, pool fire & collis																1
074						Υ	0.7		Fatalities from head on collision of	þ										0.33	66		65.67		1
							n		Speed assumed to be >=8 knots	1															Ĺ
					Y				Fatalities from head on collision of	Þ										0,33	66		65,67		1
- 1				0.0018		n	ļ.		Speed assumed to be >=8 knots	1.															
- 1				head on					Fatalities from head on collision o	Ь										0,33	66	7 18E-08	65 67	7.18E-08	3 1
		•	0.95		n		L E		Speed assumed to be >=8 knots	4															
ŀ			y	0.33					Fatalities from nudging fenders or	ψc															
- 1				nudge			- 1		Speed assumed to be >=8 knots	1															1
- 1		0.0009		0.67				4.04E-07	Fatalities from glancing fenders o	ď												i			1
- 1	[	У		inor gland	ce		Į.		Speed assumed to be >=8 knots	1															1
L	1,00	Į	0.05				:		Severe glancing impact onto struc	e															1
	n		n				L		Speed assumed to be 4 knots	J															1
	L	0.9991						7.38E-04	Boat passes under bridge	f															i
		n					L			]															1
								2.40E-09																	1
			Outcomes			Observe	F	7.40E-04		_															,

Natural gas / Oil pipeline

Head on collison > 8 knots

Nudging collision > 8 knots

Glancing collision > 8 knots
Severe glancing impact onto structure. LOP

Straight through

#### Summary Results of Event Trees for Sensitivities on Design Options 1 & 2

	tion 1																							Design	-	
																								FN		
VID	OI UP	V1 0	001 D	V2 D	O1 UP	V2 E	001 D	V3 D	OI UP	V3 I	DOLD	V4 D	OI UP	V4 E	OI D	VS D	OI UP	V5 I	001 D	V6 D	OOL UP	V6 E	01D	Data		
No. of		No. of		No. of		No. of		No. of		No. of		No. of		No. of		No. of		No. of		No. of		No. of		l	1.	Син
	Frequency		Frequency		Frequency		Frequency	Fatalities	Frequency	Fatalities	Frequency	Fatalities	Frequency	Fatalities	Frequency	Fatalities	Frequency	Fualities	Frequency	Fatalities	Frequency	Fatalities	Frequency	N	F	Freq
480		680		321	***************************************	452		277		390		248		348	• •	181	• •	252		131	• •	181	•	680	3.01E-09	3,0
264		264		173		173		149		149		132		132		94		94		66		66		480	3.18E-09	6.1
264		264		173		173		149		149		132		132		94		94		66		66		390	3.41E-09	9.
264	8.12E-08	264	1.55E-08	173	9 21E-08	173	1.75E-08	149	9.21E-08	149	1.75E-08	132	4.60E-08	132	8.77E-09	94	4 60E-08	94	8.77E-09	66	2.66E-08	66	5.06E-09	452	3.41E-09	L
																								248	8.37E-10	1.
																								277	1.67E-09	1.
																								321	1.67E-09	1.
480	1.48E-09	680	3.01E-09	321	1.67E-09	452	3,41E-09	277	1.67E-09	390	3.41E-09	248	8.37E-10	348	1.70E-09	181		252		131		181		264	1.12E-07	1
264	3.45E-09	264	7.01E-09	173	3.91E-09	173	7.95E-09	149	3.91E-09	149	7.95E-09	132	1.95E-09	132	3.97E-09	94		94		66		66		132	6,35E-08	1
264	4.92E-09	264		173	5.58E-09	173		149	5.58E-09	149		132	2.79E-09	132		94		94		66		66		149	1.27E-07	1 3
264		264		173		173		149		149		132		132		94	5.58E-09	94	5.68E-09	66	3.22E-09	66	3.28E-09	173		
																								94	6.61E-08	
																								66	3.81E-08	
																									5.51E-07	,
Design O	otton 2																						·	_	ı Optlon 2	
				1/0.0	00 III	140 F	000 D	1/2 0	COLE	***	202.5	144 B	00.170	V		W D	O2 LTD	165	200 15	<b>3</b> 76 17	Win Im	W.f		Desig FN	•	
VID	otion 2 O2 UP		002 D		O2 UP		002 D		O2 UP		DO2 D		O2 ህኮ		002 D		O2 UP		002 D		DC)2 UP		002 D	Desig	•	1-6
V1 D No. of	02 UP	No. of		No. of		No. of		No. of		No. of		No. of		No. of		No. of		No. of		No. of		No. of	002 D	Desig FN Date	T	
V1 D No. of	02 UP	No. of Fundities	DO2 D Frequency	No. of Fatalities		No. of Fatalities		No. of Faulities		No. of Futalities		No. of Futalities		No. of Faulities		No. of Fatalities		No. of Futulties		No. of Patalities	OC)2 UP Prequency	No. of Fatalities	002 D	Desig FN Data	,	F
V1 D No. of Fasalities 480	02 UP	No. of Faulities 680		No. of Fatalities 321		No. of Fatalities 452		No. of Fundities 277		No. of Futalities 390		No. of Fatalities 248		No. of Faulities 348		No. of Fatalities 181		No. of Futulties 252		No. of Fatalities 131		No. of Fstalities 181	002 D	Desig FN Data	J-1.00E-09	<b>F</b>
V1 D No. of realities 480 264	02 UP	No. of Fundities 680 264		No. of Fatalities 321 173		No. of Fatalities 452 173		No. of Finalities 277 149		No. of Futulities 390 149		No. of Finalities 248 132		No. of Fetalities 348 132		No. of Familities 181 94		No. of Futulties 252 94		No. of Paralities 131 66		No. of Fstalities 181 66	002 D	Desig FN Date N 680 480	1.00E-09	7
V1 D No. of Malities 480 264 264	02 UP Frequency	No. of Faulities 680 264 264	Frequency	No. of Fatalities 321 173 173	Frequency	No. of Fatalities 452 173 173	Frequency	No. of Finalities 277 149 149	Frequency	No. of Fatalities 390 149 149	Frequency	No. of Fatalities 248 132 132	Frequency	No. of Fatalities 348 132 132	Ресqueнсу	No. of Fatalities 181 94 94	Ftequency	No. of Futuities 252 94 94	Frequency	No. of fatalities 131 66 66	Prequency	No. of Fatalities 181 66 66	002 D Frequency	Desig FN Date N 680 480 390	1.00E-09 1.07E-09 1.14E-09	<b>J</b>
V1 D No. of Fasalities 480 264	02 UP	No. of Fundities 680 264		No. of Fatalities 321 173		No. of Fatalities 452 173		No. of Finalities 277 149		No. of Futulities 390 149		No. of Finalities 248 132		No. of Fetalities 348 132		No. of Familities 181 94		No. of Futulties 252 94		No. of Paralities 131 66		No. of Fstalities 181 66	002 D	Pesig FN Data N 680 480 390 452	1.00E-09 1.07E-09 1.14E-09	F
V1 D No. of Fashities 480 264 264	02 UP Frequency	No. of Faulities 680 264 264	Frequency	No. of Fatalities 321 173 173	Frequency	No. of Fatalities 452 173 173	Frequency	No. of Finalities 277 149 149	Frequency	No. of Fatalities 390 149 149	Frequency	No. of Fatalities 248 132 132	Frequency	No. of Fatalities 348 132 132	Ресqueнсу	No. of Fatalities 181 94 94	Ftequency	No. of Futuities 252 94 94	Frequency	No. of fatalities 131 66 66	Prequency	No. of Fatalities 181 66 66	002 D Frequency	Desig FN Data N 680 480 390 452 248	1.00E-05 1.07E-05 1.14E-05 1.14E-05 2.84E-10	F
V1 D No. of Fedities 480 264 264	02 UP Frequency	No. of Faulities 680 264 264	Frequency	No. of Fatalities 321 173 173	Frequency	No. of Fatalities 452 173 173	Frequency	No. of Finalities 277 149 149	Frequency	No. of Fatalities 390 149 149	Frequency	No. of Fatalities 248 132 132	Frequency	No. of Fatalities 348 132 132	Ресqueнсу	No. of Fatalities 181 94 94	Ftequency	No. of Futuities 252 94 94	Frequency	No. of fatalities 131 66 66	Prequency	No. of Fatalities 181 66 66	002 D Frequency	Desig FN Date N 680 480 390 452 248 277	1.00E-05 1.07E-05 1.14E-05 1.14E-05 2.84E-10 5.69E-10	1871
V1 D No. of Feralities 480 264 264 264	02 UP Frequency 7.35E-09	No. of Faculities 680 264 264 264	Frequency 7,35E-09	No. of Fatalities 321 173 173 173	Frequency 8.33E-09	No. of Fatalities 452 173 173 173	Frequency 8.33E-09	No. of Fundities 277 149 149 149	Frequency 8.33E-09	No. of Futalities 390 149 149 149	8.33E-09	No. of Fatalities 248 132 132 132	Frequency 4.17E-09	No. of Fetalities 348 132 132 132	1 <sup>2</sup> sequency 4.17E-09	No. of Fatalities 181 94 94 94	Ftequency	No. of Figulities 252 94 94 94	Frequency	No. of Paralities 131 66 66 66	Prequency	No. of Establities 181 66 66 66 66	002 D Frequency	Pesig FN Date N 680 480 390 452 248 277 321	1.00E-05 1.07E-05 1.14E-05 1.14E-05 2.84E-10 5.69E-10	2 2 2 2 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5
V1 D No. of Fashities 480 264 264 264	7.35E-09	No. of Faculities 680 264 264 264 264	7,35E-09	No. of Fatalities 321 173 173 173 173	8.33E-09 5.69E-10	No. of Fatalities 452 173 173 173	Frequency 8.33E-09	No. of Fundities 277 149 149 149	8.33E-09 5.69E-10	No. of Fatalities 390 149 149 149	8.33E-09	No. of Families 248 132 132 132	4.17E-09	No. of Fetalities 348 132 132 132	1°requency 4.17E-09 5.69E-10	No. of Familities 181 94 94 94	Ftequency	No. of Figurities 252 94 94 94	Frequency	No. of Paralities 131 66 66 66 66	Prequency	lo .oK Redituer 181 66 66 66 66	002 D Frequency	Desig FN Date N 630 439 390 452 248 277 321 264	1.00E-05 1.07E-05 1.14E-05 1.14E-05 2.84E-10 5.69E-10 1.99E-08	2 2 4
V1 D No. of Fashities 480 264 264 264	7.35E-09 5.02E-10 1.17E-09	No. of Fatalities 680 264 264 264 264	Frequency 7,35E-09	No. of Fatalities 321 173 173 173 173	8.33E-09 5.69E-10 1.33E-09	No. of Fatalities 452 173 173 173 173	Frequency 8.33E-09	No. of Fundities 277 149 149 149 277 149	8.33E-09 5.69E-10 1.33E-09	No. of Fatalities 390 149 149 149 390 149	8.33E-09	No. of Fastalities 248 132 132 132 248 132	4.17E-09 2.84E-10 6.64E-10	No. of Fedulities 348 132 132 132 348 132	1 <sup>2</sup> sequency 4.17E-09	No. of Familities 181 94 94 94 94	Ftequency	No. of Futuhities 252 94 94 94 252	Frequency	No. of featalities 131 66 66 66 66	Prequency	lo.oK Reditter 181 66 66 66 66 81	002 D Frequency	Desig FN Date 80 480 452 248 277 321 264 432	1.00E-05 1.07E-05 1.14E-05 1.14E-05 2.84E-10 5.69E-10 1.99E-06 1.13E-06	3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
V1 D No. of Fashities 480 264 264 264	7.35E-09	No. of Faculities 680 264 264 264 264	7,35E-09	No. of Fatalities 321 173 173 173 173	8.33E-09 5.69E-10	No. of Fatalities 452 173 173 173	Frequency 8.33E-09	No. of Fundities 277 149 149 149	8.33E-09 5.69E-10	No. of Fatalities 390 149 149 149	8.33E-09	No. of Fastalities 248 132 132 132 132 248 132 132	4.17E-09	No. of Fetalities 348 132 132 132	1°requency 4.17E-09 5.69E-10	No. of Familities 181 94 94 94	Ftequency	No. of Figurities 252 94 94 94	Frequency	No. of Paralities 131 66 66 66 66	Prequency	lo .oK Redituer 181 66 66 66 66	002 D Frequency	Desig FN Data N 6890 480 422 248 277 321 264 132 149	1.00E.05 1.07E.05 1.14E-05 1.14E-05 2.84E-10 5.69E-10 1.19E-05 1.13E-00 2.25E-08	
V1 D No. of Fedalities 480 264 264 264 264 480 264 264	7.35E-09 5.02E-10 1.17E-09	No. of Fatalities 680 264 264 264 264 680 264 264	7,35E-09	No. of Fatalities 321 173 173 173 173 173 173 173 173 173 17	8.33E-09 5.69E-10 1.33E-09	No. of Fatalities 452 173 173 173 173	Frequency 8.33E-09	No. of Fundities 277 149 149 149 277 149 149 149 149 149 149 149 149	8.33E-09 5.69E-10 1.33E-09	No. of Futalities 390 149 149 149 149	8.33E-09	No. of Fastalities 248 132 132 132 248 132	4.17E-09 2.84E-10 6.64E-10	No. of 1944 lifes 348 132 132 132 132 132 132 132 132 132 132	1°requency 4.17E-09 5.69E-10	No. of Fatalities 181 94 94 94 94	Frequency 4.17E-09	No. of Futulties 252 94 94 94 252 94	Frequency 4,17E-09	No. of featalities 131 66 66 66 131 66 66 66	Frequency 2.40E-09	10. OK 181 181 66 66 66 66 181 181 66	002 D Frequency 2.40E-09	Desig FN Dash N 6890 499 452 248 277 321 264 132 149 173	1.00E.05 1.07E-05 1.14E-05 1.14E-05 1.14E-05 1.14E-05 1.14E-05 1.13E-06 1.13E-06 1.13E-06 2.25E-06	
V1 D No. of Fedalities 480 264 264 264 264 480 264 264	7.35E-09 5.02E-10 1.17E-09	No. of Fatalities 680 264 264 264 264 680 264 264	7,35E-09	No. of Fatalities 321 173 173 173 173 173 173 173 173 173 17	8.33E-09 5.69E-10 1.33E-09	No. of Fatalities 452 173 173 173 173	Frequency 8.33E-09	No. of Fundities 277 149 149 149 277 149 149 149 149 149 149 149 149	8.33E-09 5.69E-10 1.33E-09	No. of Futalities 390 149 149 149 149	8.33E-09	No. of Fastalities 248 132 132 132 132 248 132 132	4.17E-09 2.84E-10 6.64E-10	No. of 1944 lifes 348 132 132 132 132 132 132 132 132 132 132	1°requency 4.17E-09 5.69E-10	No. of Fatalities 181 94 94 94 94	Frequency 4.17E-09	No. of Futulties 252 94 94 94 252 94	Frequency 4,17E-09	No. of featalities 131 66 66 66 131 66 66 66	Frequency 2.40E-09	10. OK 181 181 66 66 66 66 181 181 66	002 D Frequency 2.40E-09	Desig FN Date 80 480 452 248 277 321 264 432 132 149 173	1.00E-05 1.07E-05 1.14E-05 2.84E-16 5.69E-10 1.99E-06 1.13E-08 2.25E-06 2.25E-06	
V1 D No. of Fedalities 480 264 264 264 264 480 264 264	7.35E-09 5.02E-10 1.17E-09	No. of Fatalities 680 264 264 264 264 680 264 264	7,35E-09	No. of Fatalities 321 173 173 173 173 173 173 173 173 173 17	8.33E-09 5.69E-10 1.33E-09	No. of Fatalities 452 173 173 173 173	Frequency 8.33E-09	No. of Fundities 277 149 149 149 277 149 149 149 149 149 149 149 149	8.33E-09 5.69E-10 1.33E-09	No. of Futalities 390 149 149 149 149	8.33E-09	No. of Fastalities 248 132 132 132 132 248 132 132	4.17E-09 2.84E-10 6.64E-10	No. of 1944 lifes 348 132 132 132 132 132 132 132 132 132 132	1°requency 4.17E-09 5.69E-10	No. of Fatalities 181 94 94 94 94	Frequency 4.17E-09	No. of Futulties 252 94 94 94 252 94	Frequency 4,17E-09	No. of featalities 131 66 66 66 131 66 66 66	Frequency 2.40E-09	10. OK 181 181 66 66 66 66 181 181 66	002 D Frequency 2.40E-09	Desig FN Dash N 6890 499 452 248 277 321 264 132 149 173	1.00E.05 1.07E.05 1.14E-05 1.14E-05 2.84E-10 5.69E-10 1.19E-08 2.25E-05 2.25E-06 4.99E-05 6.99E-05	2 2 3 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
V1 D No. of malities 480 264 264 264 480 264 264	7.35E-09 5.02E-10 1.17E-09	No. of Fatalities 680 264 264 264 264 680 264 264	7,35E-09	No. of Fatalities 321 173 173 173 173 173 173 173 173 173 17	8.33E-09 5.69E-10 1.33E-09	No. of Fatalities 452 173 173 173 173	Frequency 8.33E-09	No. of Fundities 277 149 149 149 277 149 149 149 149 149 149 149 149	8.33E-09 5.69E-10 1.33E-09	No. of Futalities 390 149 149 149 149	8.33E-09	No. of Fastalities 248 132 132 132 132 248 132 132	4.17E-09 2.84E-10 6.64E-10	No. of 1944 lifes 348 132 132 132 132 132 132 132 132 132 132	1°requency 4.17E-09 5.69E-10	No. of Fatalities 181 94 94 94 94	Frequency 4.17E-09	No. of Futulties 252 94 94 94 252 94	Frequency 4,17E-09	No. of featalities 131 66 66 66 131 66 66 66	Frequency 2.40E-09	10. OK 181 181 66 66 66 66 181 181 66	002 D Frequency 2.40E-09	Desig FN Date 80 480 452 248 277 321 264 432 132 149 173	1.00E.05 1.14E.05 1.14E.05 1.14E.05 1.3E.06 1.3E.06 1.3SE.06 1.3SE.06 1.2SE.06 1.2SE.06 1.2SE.06 1.2SE.06 1.2SE.06 1.2SE.06 1.2SE.06 1.2SE.06 1.2SE.06	
V1 D No. of malities 480 264 264 264 480 264 264	7.35E-09 5.02E-10 1.17E-09 1.67E-09	No. of Fatalities 680 264 264 264 264 680 264 264	7.35E-09 1.00E-09 2.34E-09	No. of Fatalities 321 173 173 173 173 173 173 173 173 173 17	5.695-10 1.336-09 1,90E-09	No. of Fatalities 452 173 173 173 173	Frequency 8.33E-09 1.14E-09 2.65E-09	No. of Fundities 277 149 149 149 277 149 149 149 149 149 149 149 149	8.33E-09 5.69E-10 1.33E-09 1.90E-09	No. of Futalities 390 149 149 149 149	8.33E-09 1.14E-09 2.65E-09	No. of Fastalities 248 132 132 132 132 248 132 132	4.17E-09  2.84E-10  6.64E-10  9.48E-10	No. of 1944 lifes 348 132 132 132 132 132 132 132 132 132 132	Prequency 4.17E-09 5.69E-10 1.33E-09	No. of Fatalities 181 94 94 94 94	Frequency 4.17E-09 1.90E-09	No. of Futulties 252 94 94 94 252 94	Frequency 4,17E-09 1,90E-09	No. of featalities 131 66 66 66 131 66 66 66	2.40E-09	10. OK 181 181 66 66 66 66 181 181 66	DO2 D Frequency 2.40E-09	Desig FN Date 80 480 452 248 277 321 264 432 132 149 173	1.00E-05 1.07E-05 1.14E-05 1.14E-05 2.84E-10 5.69E-10 1.19E-06 2.25E-05 2.25E-06 4.99E-05 6.99E-05	

## Summary Frequency Results of Event Trees for Sensitivities of Design Options 1 & 2

### Design Option 1

Frequency of		1 DO1	2 DO1 U	2 DO1	3 DO1 U	3 DO1	4 DO1 U	4 DO1	5 DO1 U	5 DO1	6 DO1 U	6 DO1 D	1		sign option 1 ency of Collisio
Fatalities from jet, pool fire & co														Nav span collision	
Fatalities from head on collision														Head on	4.6.E-07
Fatalities from head on collision	•													Glance	2.7.E-04
Fatalities from head on collision	n 8.12E-08	1.55E-08	3 9.21E-08	1.75E-08	9.21E-08	1.75E-08	3 4.60E-08	8.77E-09	4.60E-08	8.77E-09	2.66E-08	5.06E-09	4.6.F-07	n nav snan collicion	
ratainties from nuoging tenders	1.50E-05	2.86E-08	3 1.70E-05	3.24E-06	3 1.70E-05	3.24E-06	8.51E-06	1.62E-08	8.51F-06	1.62F-06	4 91F-06	9.355-07	8 5 E-05	Haadan	9.4.E-08
ratalities from glancing fenders	3.001,05	5.72E-0	3.40E-05	6.48E-06	3.40E-05	6.48E-06	3 1.70E-05	3.24E-06	3 1 70F-05	3 24F-06	9.825-06	1.875-08	175.04	Clause	5.5.E-05
Severe glancing impact onto st	2.38E-06	4.52E-07	7 2.69E-06	5.13E-07	2.69E-06	5.13E-07	7 1.35E-06	2.56E-07	7 1 35F-06	2.56E-07	7 77E-07	1 495.07	12 5 05		
Fatalities from jet, pool fire & co	1.48E-09	3.01E-09	1.67E-09	3.41E-09	1.67F-09	3.41E-09	8.37E-10	1 70F-00	1.002 00	2.000.01	1.1112-01	1.400-07	1.7.E-08	•	
Fatalities from head on collision	3.45E-09	7.01E-09	3.91F-09	7.95E-09	3.91F-09	7 955-00	1 955-00	3.075.00	, 1						2.1.E-02
Fatalities from head on collision	4.92E-09		5.58E-09		5.58E-09		2.79E-09		,				4.0.E-08	0.1001	1
Fatalities from head on collision			0,000		J.JOE-09		2.79=-09		E COE 00				1.9.E-08		
		1 955.06	2 OPE OP	2 400 00	2.000.00	~ 400 00	4 005 00	4 055 04	5.58E-09	5.68E-09	3.22E-09	3.28E-09	1.8.E-08		
Fatalities from nudging fenders	7.02E-00	2 705 00	2.00E-00	2.10E-00	2.06E-06	2.10E-00	1.03E-06	1.05E-06	1.03E-06	1.05E-06	5.95E-07	6.05E-07	1.7.E-05		
Fatalities from glancing fenders	3.04E-00	3.70E-00	4.13E-06	4.20E-06	4.13E-06	4.20E-06	2.06E-06	2.10E-06	2.06E-06	2.10E-06	1.19E-06	1.21E-06	3.5.E-05		
Severe glancing Impact onto st	2,88E-07	2.93E-0/	3.26E-07	3.32E-07	3.26E-07	3.32E-07	1.63E-07	1.66E-07	1.63E-07	1.66E-07	9.41E-08	9.58E-08	2.7.E-06		
boat passes under bridge	2.21E-03	2,25E-03	2.50E-03	2.55E-03	2,50E-03	2.55E-03	1.25E-03	1.27E-03	1.25E-03	1.27E-03	7.22E-04	7.35E-04	2.1.E-02		
	2.26E-03	2.26E-03	2.56E-03	2.56E-03	2.56E-03	2.56E-03	1.28E-03	1.28E-03	1.28E-03	1.28E-03	7.40E-04	7.40F-04	2 1 F-02		

#### Design Option 2

Frequency of	1 002 11	1 002	200211	3 003	3 003 11	2 002	4.000.11	4.000	6 B 0 0 1 1					De	sign option 2
Fatalities from jet,pool fire & c		1002	20020	2 002	3 002 0	3 002	4 DO2 0	4 002	5 002 0	5 002	6 DO2 U	6 DO2 D		Frequ	ency of Collisio
Fatalities from head on collision														Nav span collision	
Fatalities from head on collision														Head on	6.9.E-08
		7 355-00	3 8 33E 00	0 225 00	0 225 00	0.000.00	4470 00	4.475.00						Glance	4.1.E-05
Fatalities from head on collision Fatalities from pudging fender	* 136F_06	1.365-04	9 0.53E-09	4.54E.00	0.335-09	0.33E-US	4.17E-09	4.1/E-09	4.1/E-09	4.17E-09	2.40E-09	2.40E-09 6	.9.E-08	n nav span collision	
Fatalities from nudging fender Fatalities from glancing fender	s 2.72F-06	7.50E-00	3 795 06	2 000 00	1.04E-00	2.045-00	7.70E-07	7.70E-07	7.70E-07	7.70E-07	4.44E-07	4.44E-07 1	.3.E-05	Head on	3.2.E-08
Fatalities from glancing fender	t 2 15E-07	2.125-00	7 2 445 07	3.UOE~U0	3.00E-00	3.08E-06	1.54E-06	1.54E-06	1.54E-06	1.54E-06	8.88E-07	8.88E-07 2	.6.E-05	Glance	1.8.E-05
Severe glancing impact onto s Fatalities from jet pool fire & c	n 5.02F-10	1 005-0	2.44E-U/	4.44E-0/	2.44E-U/	2.44E-U/	1.22E-U/	1.22E-07	1.22E-07	1.22E-07	7.03E-08	7.03E-08 2	.0.E-06	Pass through	2.1.E-02
Fatalities from head on collision	n 1 17E-09	2 34E_00	1 235.00	2 655 00	4 335 00	1.145-09	2.84E-10	5.69E-10	)			5	.8.E-09		2.1.E-02
Fatalities from head on collision	n 1.67E-00	2.076	1.90E-09	2.035-09					İ			1	.3.E <b>-0</b> 8	check	1
Fatalities from head on collision			1.300-03		1.90E-09		9.48E-10						.4.E-09		
		6 10E 07	7 7 04 5 07	704507	7.045.07	7 645 67	0.545.55		1.90E-09	1.90E-09	1.09E-09	1.09E-09 6	.0.E-09		
Fatalities from nudging fender:	e 1 24E-06	1 245 06	7.07E-07	1.015-07	7.01E-07	7.U1E-U7	3.51E-07	3.51E-07	3.51E-07	3.51E-07	2.02E-07	2.02E-07 5.	.8.E-06		
Fatalities from glancing fender Severe glancing impact onto s	5 1.24E-00 f 0 70F-08	0.705_09	1.405-00	1.405-00	1.401:-06	1.40E-06	7.01E-07	7.01E-07	7.01E-07	7.01E-07	4.04E-07	4.04E-07 1.	.2.E-05		
Severe glancing impact onto s Boat passes under bridge	2 265-03	2.785-00	2 565 02	1.11E-U/ 2.66E-02	1.116-07	1.11E-0/	5.55E-08	5.55E-08	5.55E-08	5.55E-08	3.20E-08	3.20E-08 9.	.3.E-07		
The property distribution bridge	2,200-00	2.205-03	2.00E-03	Z.30E-U3	2.06E-03	2.56E-03	1.28E-03	1.28E-03	1.28E-03	1.28E-03	7.38E-04	7.38E-04 2.	1.E-02		
	2.20E-U3	2.20E-03	2.00E-03	2.56E-03	2.56E-03	2.56E-03	1.28E-03	1.28E-03	1.28F-03	1 28F-03	7 405-04	7.40E-04 2	1 = 02		



# Appendix 4

Frequency Questionnaire Data

Drangli

Boent Name	No. of timetabled journeys (per week)	No. of charters on average (per week)	Operating on the Swap river (No. of Yrs)	Max Book Capacity (people)	(séprox)	Gross tommige	Boat Width	Average speed through bridge	Any instances of boat glenning Prenantle boidge (please quantify)	Comments Your view on the Fremantle Bridge, suggestions, problems encountered, eg river traffic, tide, bridge slignment, etc
Capatain Cocak	14	2	1972	310		155	68.	8 Kais		IT WOULD BE GATAT TO REMOVE THE CENTRE AREM AND THEREFORE INCREASE
Januares Stir-Ling	14	2	1995	400		135 135	8·1 a	8 KATS	GLANCES EN BECTI-LE	THE WIDTH of BOTH NITHER STA PROCESS INCRESSE THE HEART OF THE NITH ARCH WHICH IS
Sween: Exp>l orer	14	2	1956	180		75	7·1m	8 kms	からいこく	THOSES,  IF YOU NEED ANY FURTHER INTO PLEASE CH
Angy Other Do	ESS OMNICO IDEL	many pass make	r the Premante Br	R <b>age</b>						Regards MARK DSWALD (015 081 313)
	·									

Required Francis - Francis

FIX. 13223577. TO! STEVE COOPER QEST CONSULTING GROUP. Drught FROM; TONY DILATTE Your view on the Presente Bridge, NAME AND ADDRESS OF THE PARTY OF THE PARTY. OCEANIC CRUISES. Chive traffic ich bridge shipman, ex 10-11-1998 Any instances of THE RALLWAY BRIDGE & boot stacing THE OLD TEAFFIC BRIDGE ALEESES. Promote wider speed Groce SHOULD BE IN LINE (please quantify) % full 1000385 Daough WITH ENCH OTHER THAT THERE Max Book (approx) mide. Operation on Capacity (people) the Swan No. of IS A STRONG CURRENT 10 KMB1 river. charters on No of Bost Name (No. of Y18) nestal fed 63. AT TIMES , WHICH COUNT. M. CLASS 50% (per week) 18 just of 284 YORKSDEY'S CAUSE AN ACCIDENT. (per week) NIL Sea Cal THE HEIGHT OF THE 28 BRIDGE SHOULD BE 1-8 INCOUNCED BY Any other 1.5M AS WELL AS books that part Part 1. SHWIDER IN through the BETWEEN THE PYLONS Fremente Bridge 6.4 I ICKIS 3 years 199. 144 60% 0.9 SUPERCAT 4 18 KH1095) 24 37 30/0 1167. 3 years 6 CLA SSERIE 10 KNOPS 32 121. Pg {9 114 TOTAL P. 62 New. 4 રાજા COMMERCIAL IRWERCAT! 32

BONT CARRYE 10351 Boat Name No. of No. of Operating on Max Boat % full Gross Boat Average Any instances of Comments timetabled charters on the Swan river Capacity (approx) Width tonnage speed boat glancing Your view on the Fremantle Bridge, suggestions. iournevs average (No. of Yrs) (people) through Fremantle bridge problems encountered. (per week) (per week) bridge (please quantify) eg river traffic, tide, bridge alignment, etc Superflyte 1/yr made Porced to do degley 525 40% Sca Flyte Rothern Spin, sets onto the concrete span of rollway brodge forced across, 90% Star Flite movementale trafic big problem, linear 400 m '603 40% 10 0 1/2 nulyes density) Rottnest Explorer 80,3 40% 额月 500 10 mis concrete, pit m and a be.

leads hanging down centre of

Sons, Soom long, hanging webside

of bridge, 47m Any other boat you may own (SSim SHetz migin) D File markings on bridge,

poton Shirling traffic bridge, -