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Risk Assessment for Fremantle Traffic Bridge Design Options

for

Main Roads WA

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1.0 EXECUTIVE SUMMARY

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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 **5.5×10^{-7} pa** and for design option 2 is **1.0×10^{-7}** pa.
- The current cumulative frequency of glancing collisions with the navigational spans is **1.6×10^{-4}** pa. The overall cumulative frequency of a glancing collision DO 1 is **2.7×10^{-4} pa**, an increase of 72% and for DO 2 is **4.1×10^{-5} 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.

Figure 1.1 Suggested Societal Risk Criteria for Kwinana
(Industrial Developments Only)

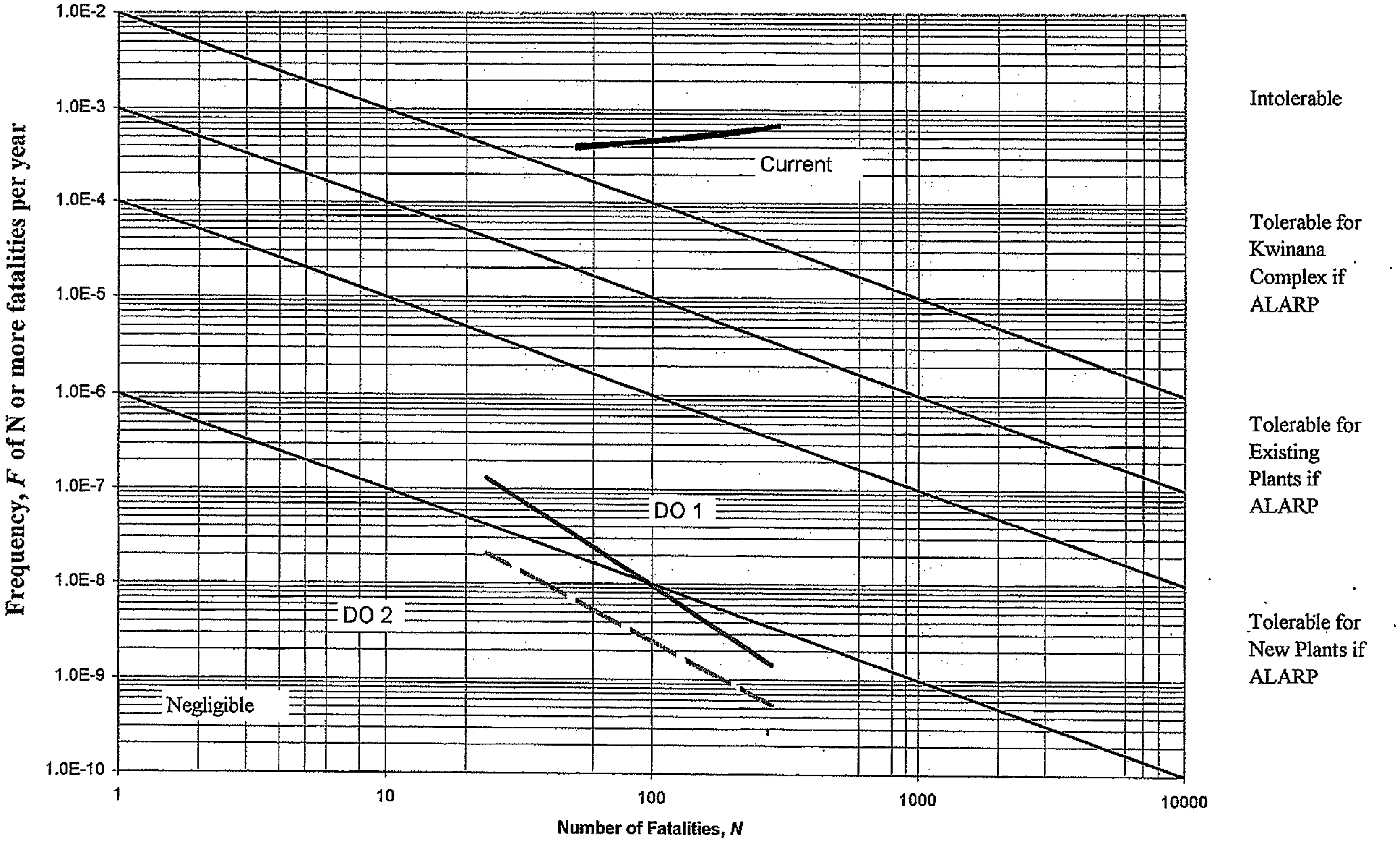

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Table 1.1 Risk Related Advantages and Disadvantages of Design Options

Task		Design Option 1 Dolphins and fender strengthening	Design Option 2 Widening the Navigation span
Approach to the bridge From up/down river	+ 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.
	- 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

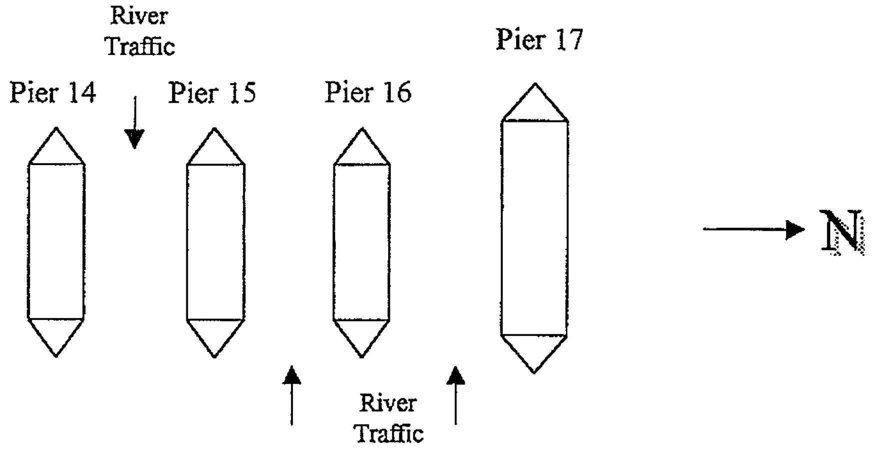
The Fremantle Traffic Bridge was constructed in 1938 and carries Queen Victoria Street from Stirling Highway over the Swan River upstream of Fremantle harbour. The bridge is one of the important arteries in Perth's road system supporting an average of 30,100 vehicles per day among other utility services, 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



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2.1 *Option 1 - Dolphin and Fender Strengthening*

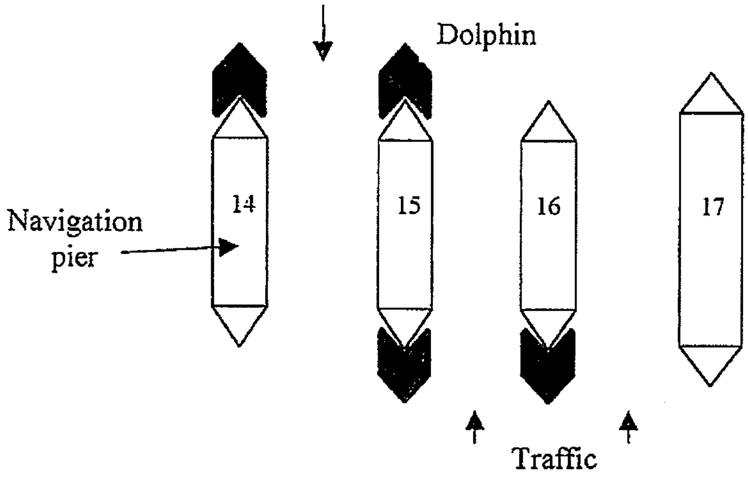
From the previous study completed on the bridge concerns were raised about the strength of the navigation span piers and protection provided by existing fenders if a head-on vessel collision occurred. The addition of dolphins and fender strengthening will be designed to provide ample protection for such 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 strengthening
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.

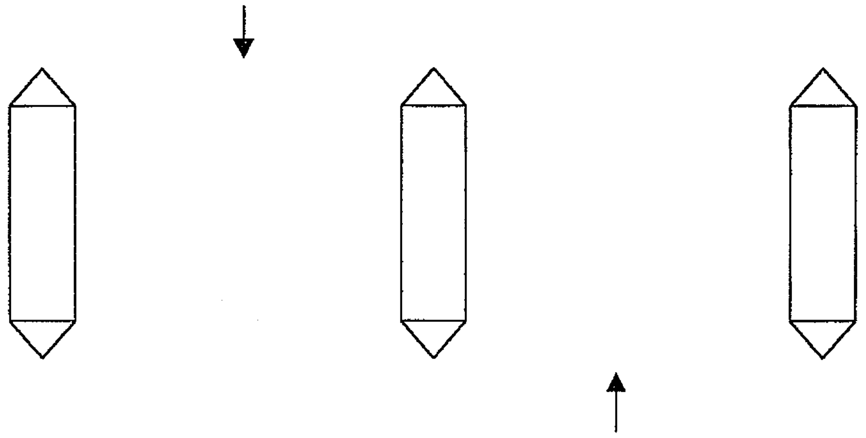
Figure 2.2 Design Option 1 for Fremantle Traffic Bridge



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

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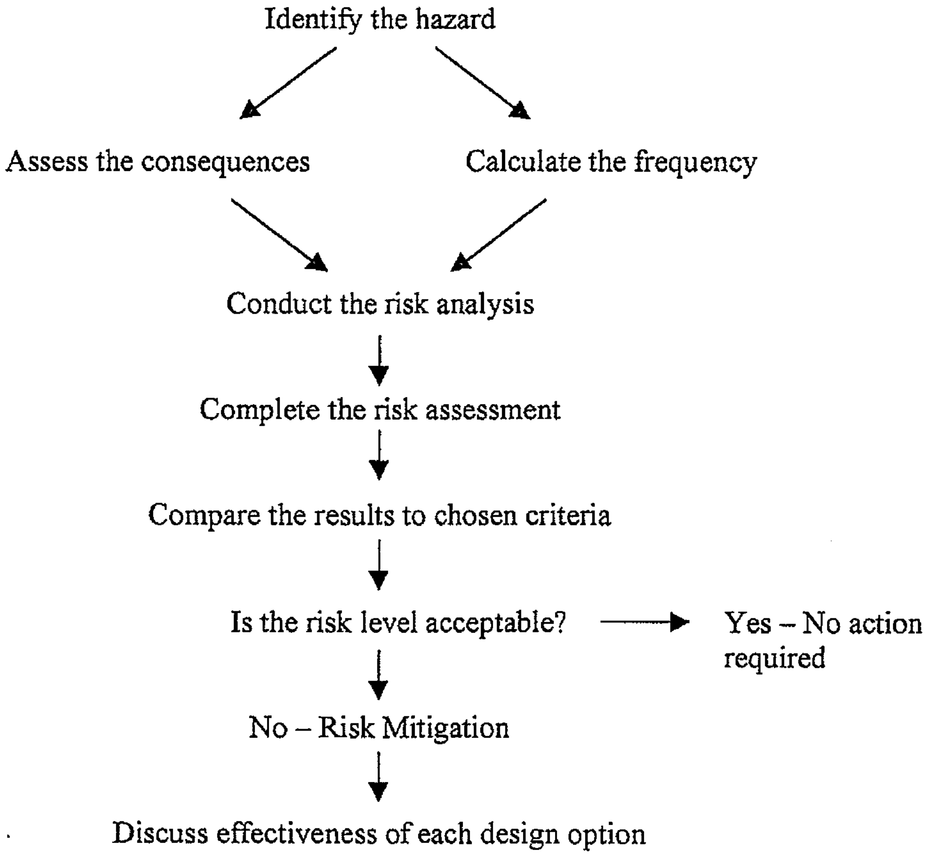
3 Methodology

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.



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.

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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
V1	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.

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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

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

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
V1	800	320	40
V2	525	210	40
V3	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.

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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^2 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/m^2 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
		10	29	11.8	<5

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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 23KW/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.

APPROACH

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

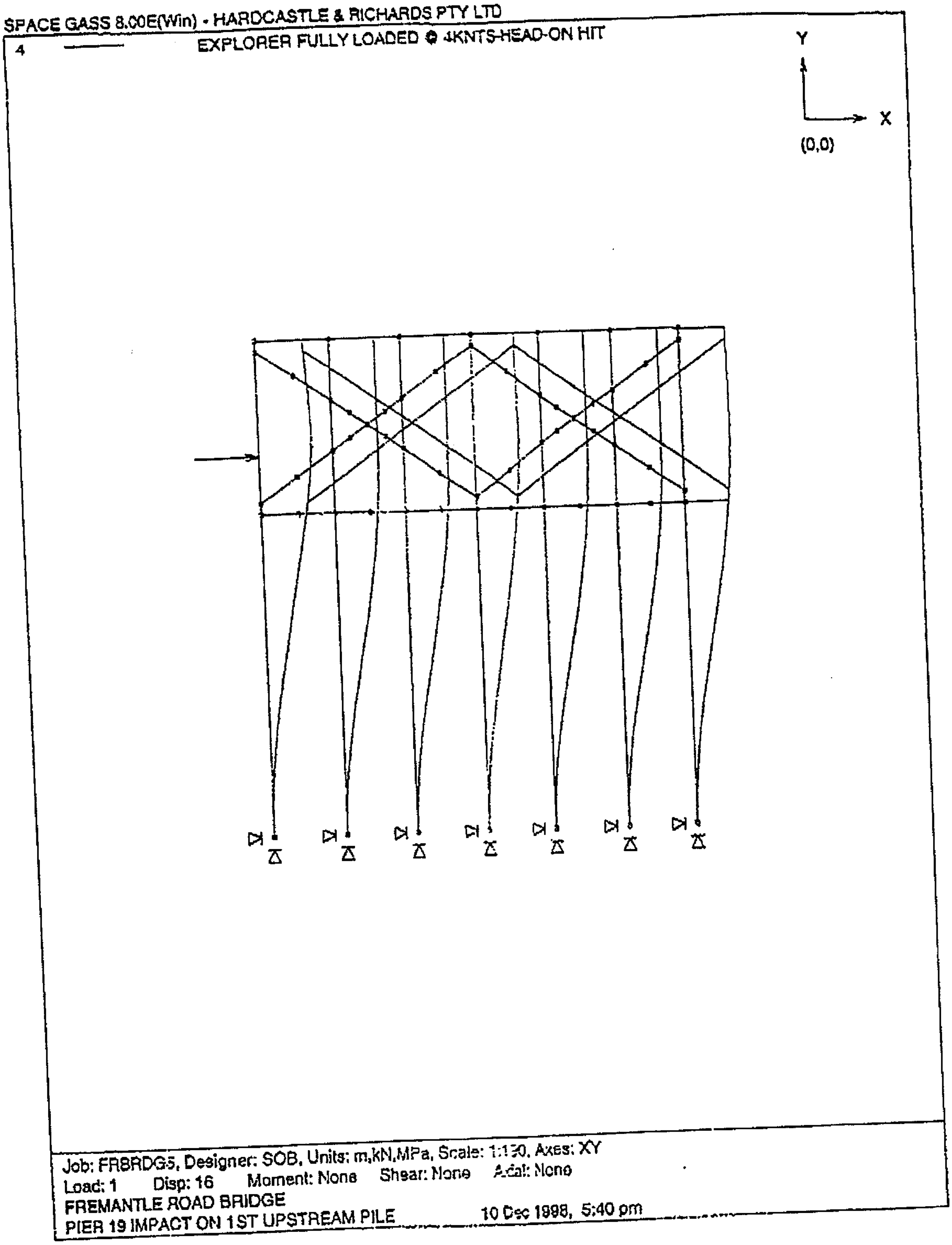
It has been assumed that these estimates of crushing distance are maximum values and that where a vessel strikes a structure, which is "soft" or yielding, then the crushing damage is reduced. In order to be able to assign a magnitude to the crushing distance for such events, the following assumptions 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 1st 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.

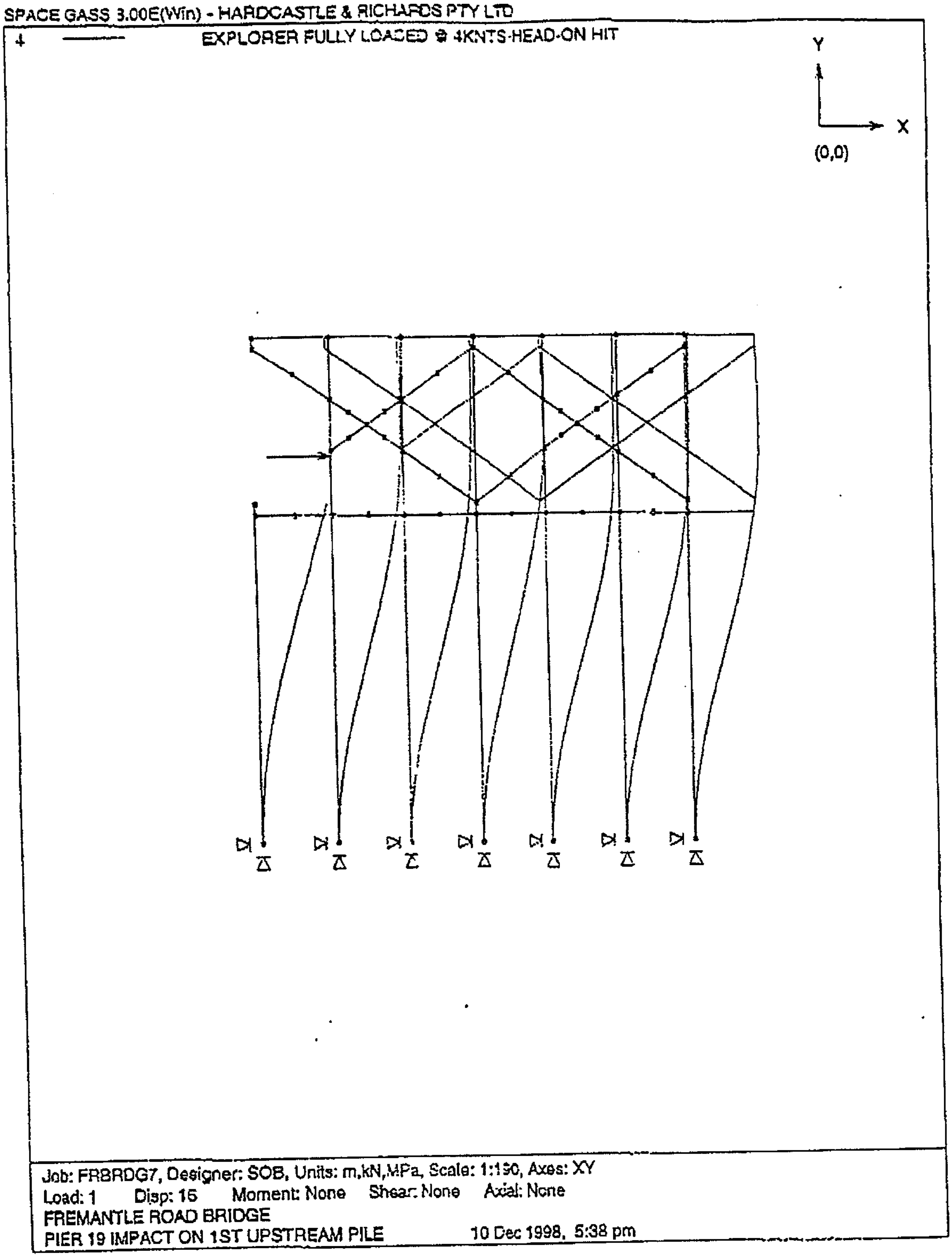


SPACE GASS 8.00E(Win) - HARDCASTLE & RICHARDS PTY LTD

4 ——— EXPLORER FULLY LOADED @ 4KNTS-HEAD-ON HIT

Job: FR8RDG5, Designer: SOB, Units: m,kN,MPa, Scale: 1:130, Axes: XY
Load: 1 Disp: 16 Moment: None Shear: None Axial: None
FREMANTLE ROAD BRIDGE
PIER 19 IMPACT ON 1ST UPSTREAM PILE 10 Dec 1998, 5:40 pm

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



SPACE GASS 3.00E(Win) - HARDCASTLE & RICHARDS PTY LTD

EXPLORER FULLY LOADED @ 4KNTS HEAD-ON HIT

Job: FRBRDG7, Designer: SOB, Units: m,kN,MPa, Scale: 1:150, Axes: XY
Load: 1 Disp: 15 Moment: None Shear: None Axial: None
FREMANTLE ROAD BRIDGE
PIER 19 IMPACT ON 1ST UPSTREAM PILE 10 Dec 1998, 5:38 pm

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.

APPROACH

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 Collision 4 knots (2m/s)		Head on Collision 10 knots (5m/s)	
Vessel	**Initial Energy (kNm)**	**Deceleration (m/s^2)**	**Initial Energy (kNm)**	**Deceleration (m/s^2)**
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/s^2)**	**Initial Energy (kNm)**	**Deceleration (m/s^2)**
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 Option 1			Design Option 2		
N	F	Cumulative Frequency	N	F	Cumulative Frequency
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

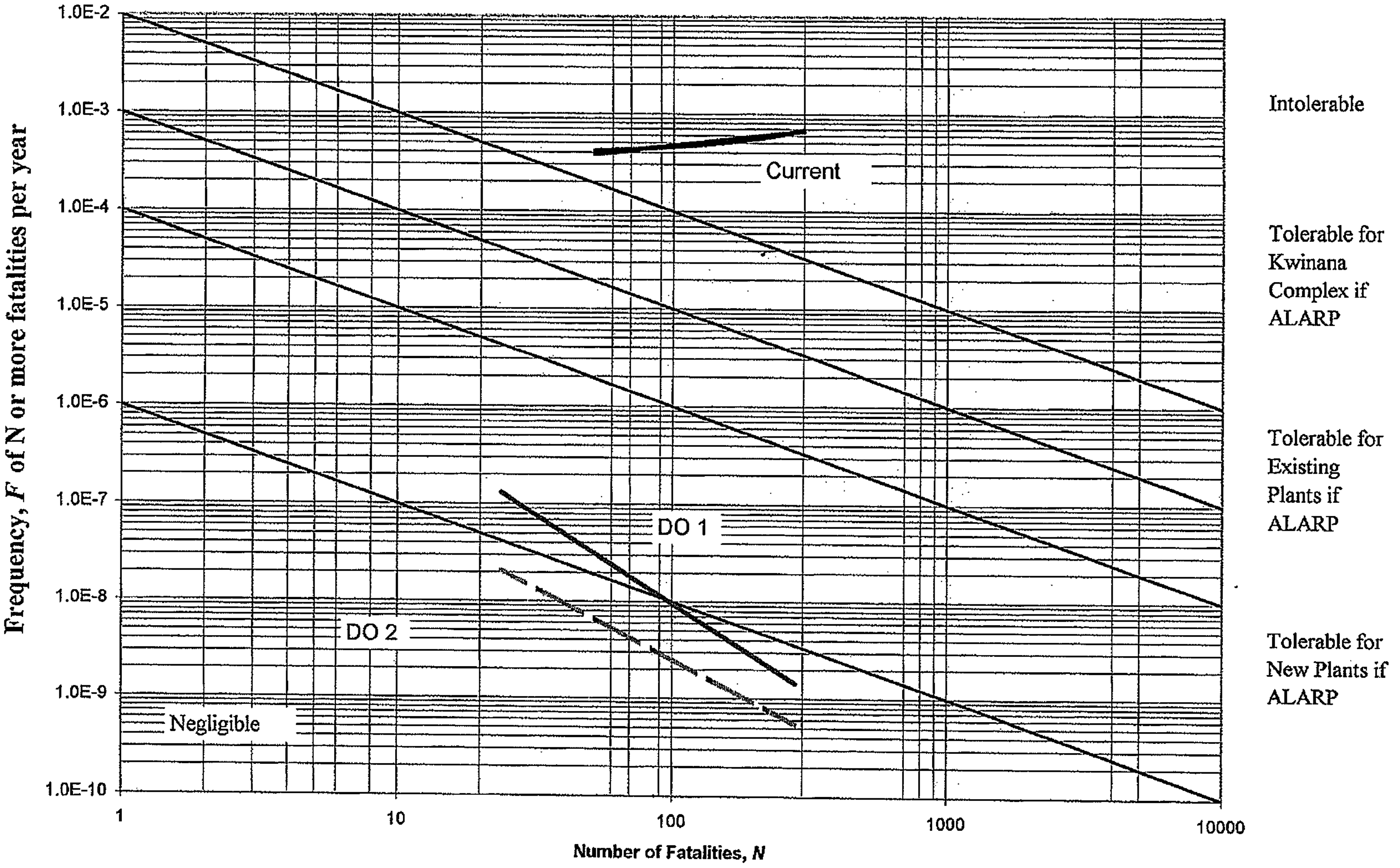
The cumulative frequency of collisions resulting in a fatality for design option 1 is **5.5 x 10^{-7} pa** and for design option 2 is **1.0 x 10^{-7} pa**. Table 4.2 shows the frequency for the Fremantle Traffic Bridge and compares it with the criteria set out by Austroads and the US Department of Transportation.

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	Y	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.

Figure 4.2 Suggested Societal Risk Criteria for Kwinana
(Industrial Developments Only)



FINDINGS

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/ m$Aus	Frequency	Factor (f$)
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.

FINDINGS

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 Frequency			Change %	
Collision Type	Current	DO 1	DO 2	DO 1	DO 2
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

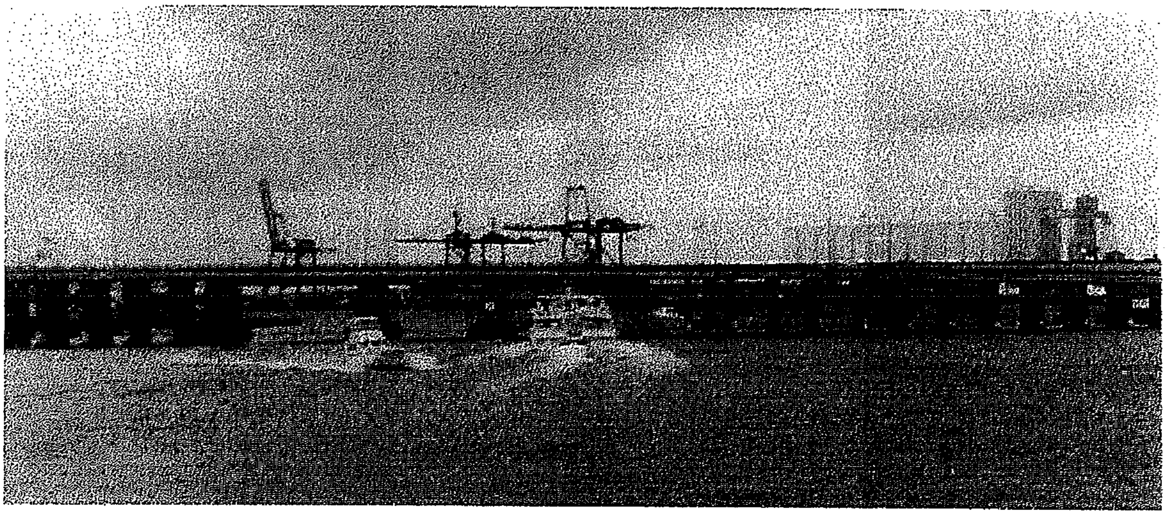


Figure 4.4 Captain Cooks "James Stirling" vessel prior to traversing the Traffic Bridge from upstream through the small Middle Span

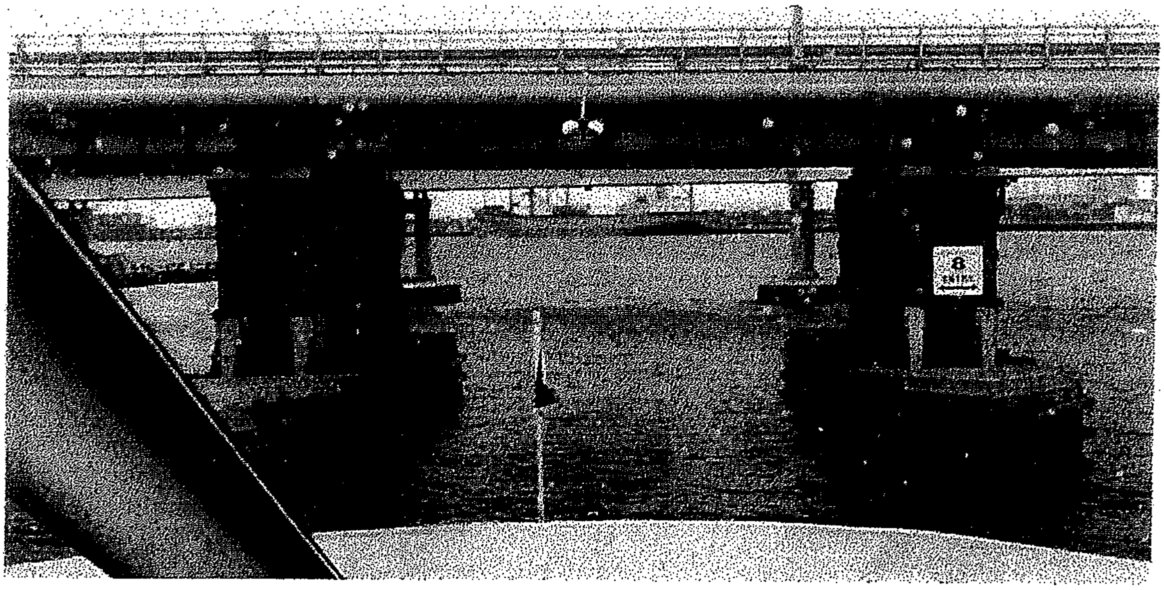
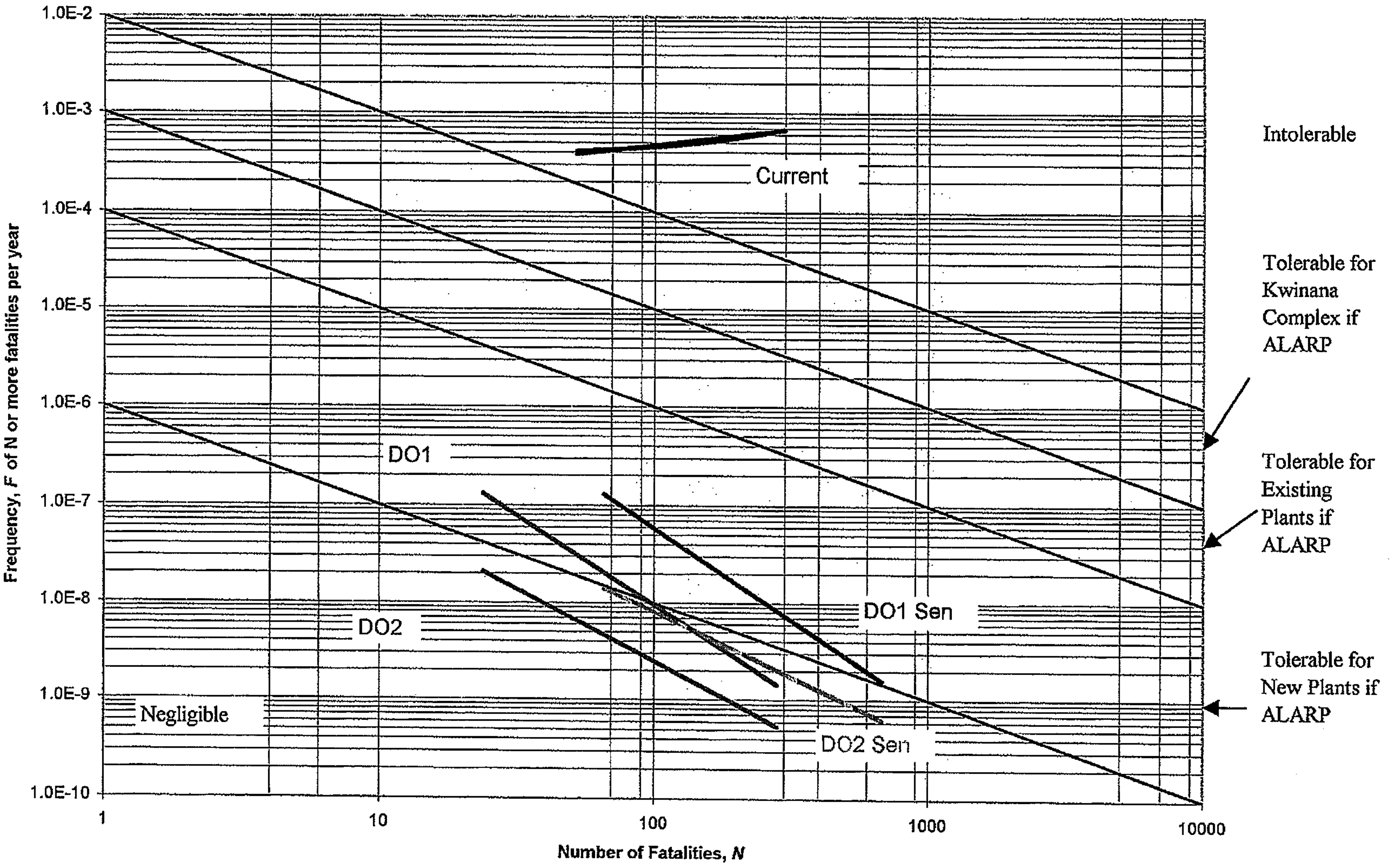


Figure 4.5 Suggested Societal Risk Criteria for Kwinana (Industrial Developments Only)



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

	Basecase		Sensitivity	
Vessel	Fatality Rate	Passengers estimated on board	Fatality Rate	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

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 **5.5×10^{-7} pa** and for design option 2 is **1.0×10^{-7} pa**.
- The current cumulative frequency of glancing collisions with the navigational spans is **1.6×10^{-4} pa**. The overall cumulative frequency of a glancing collision DO 1 is **2.7×10^{-4} pa,** an increase of 72% and for DO 2 is **4.1×10^{-5} 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 Dolphins and fender strengthening	Design Option 2 Widening the Navigation span
Approach to the bridge From up/down river	+ 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.
	- 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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[2] Austroads, Austroads Bridge Design Code – Limit States Format, Section C1 1992

[3] Chamberlain, Developments In design methods for predicting thermal radiation from flares, Chem Eng Res Des, Vol 65, July 1987

[4] A.D. Johnson, H.M.Brightwell, A.J.Carsley, A model for predicting the thermal radiation hazards from large scale horizontally released natural gas jet fires, Trans IChemE, Vol 72, Part B, Aug 1994

[5] A.J.Carsley, A model for predicting the probability of impingement of jet fires, IChemE Symposium Series 139, Major Hazards Onshore and Offshore II, Oct 95

[6] Hazardous Industry Planning Advisory paper No. 2, Fire Safety Guidelines, Department of Planning Sydney, 1993

[7] Uniform Shipping laws Code Section 5 Sub Section C, Section C.2 and C.3, Australian Government Publishing Service Canberra, 1993

[8] Uniform Shipping laws Code Section 5 Sub Section C, Appendix 1, Australian Government Publishing Service, 1993

[9] Loss Prevention in the Process Industry, Lees pp448 ISBN 0-408-10604-2

[10] Water Transport pg4, E&P Forum, QRA Directory Rev0 pg4, 1996

8.0 APPENDICES

Appendix 1

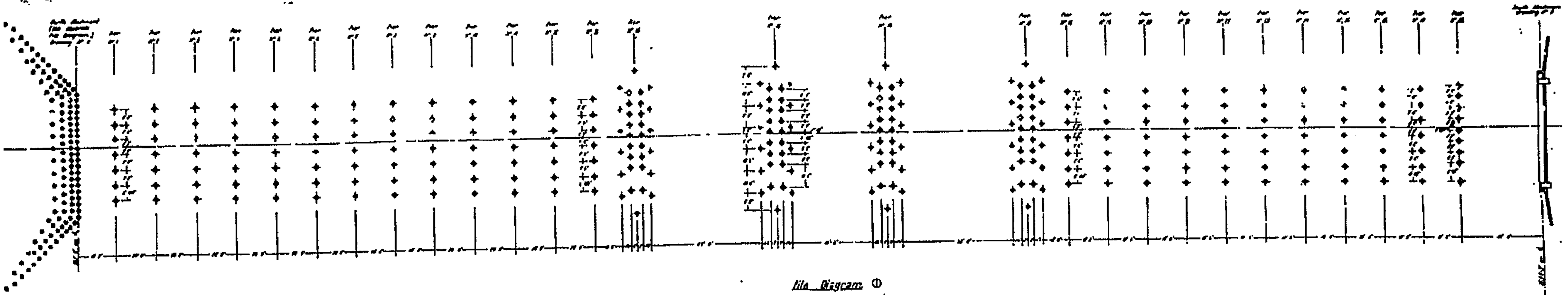
General Arrangement Drawings of Design Options

Main Roads Department, Western Australia.

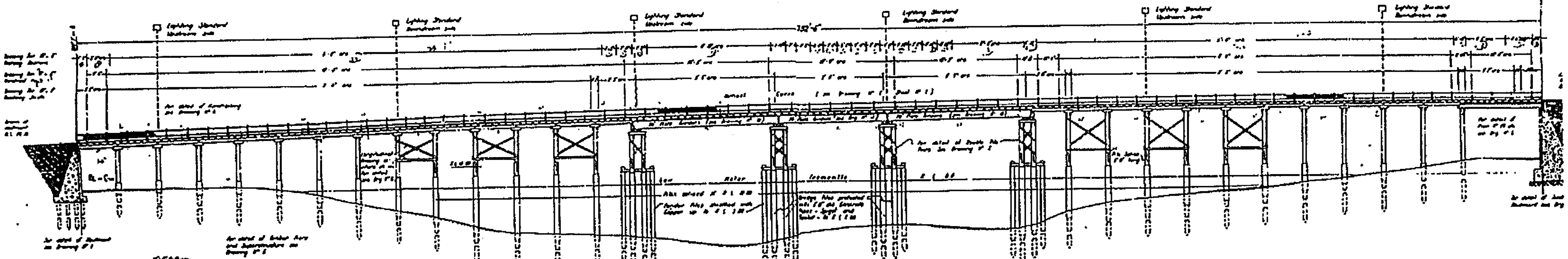
Fremantle Traffic Bridge.

General Layout etc.

Scales: ① ②

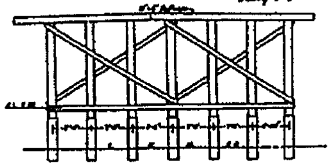


Pile Diagram ①

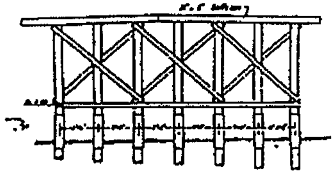


Note:
All piles driven to a depth of 20'0"

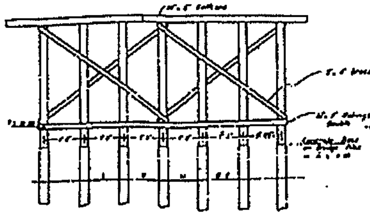
Longitudinal Section ①



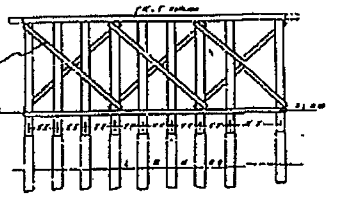
Type Cross Bracing. Piers 6 & 7 & 24 to 27 inclusive. ②



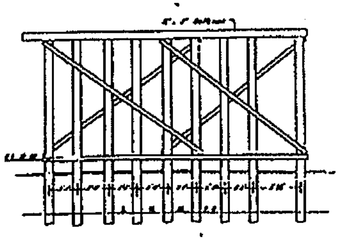
Type Cross Bracing. Pier 1 to 5 inclusive. ②



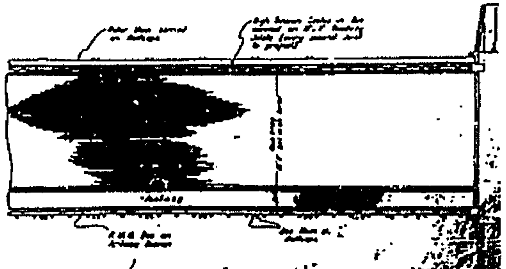
Type Cross Bracing. Piers 8 to 13 inclusive & 18 to 23 inclusive. ②



Type Cross Bracing. Piers 14 to 17 inclusive ①



Pier Bracing. Pier 28. ①



Part Plan ①

Main Roads Department, Western Australia.

Fremantle Traffic Bridge.

Details of Timber Spans.

Scale 4 Feet to 1 Inch

Municipalities.

Timber

[illegible]

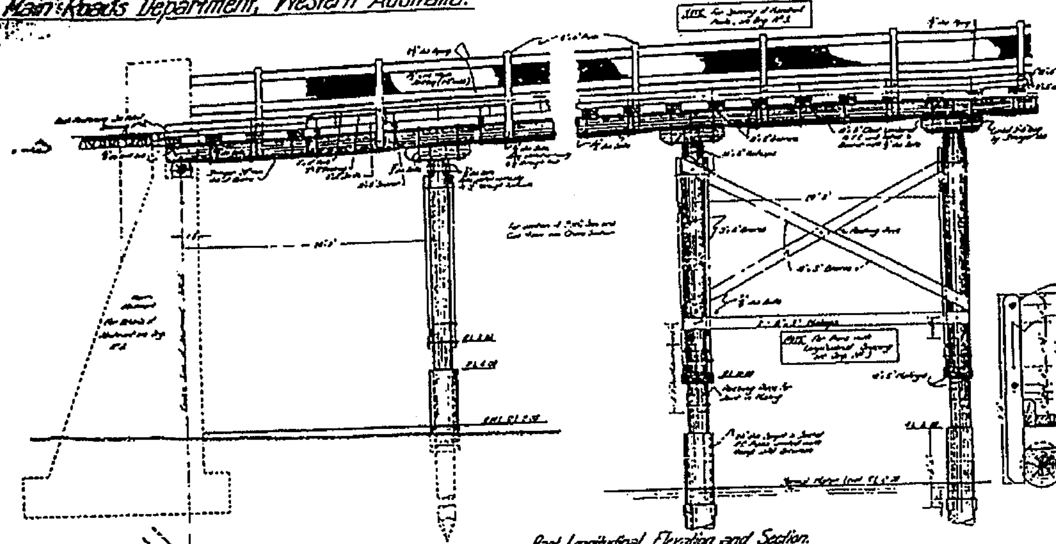
Longitudinal packing pieces on 40' spans are sawn wandoo

All other sawn timber is jarrah

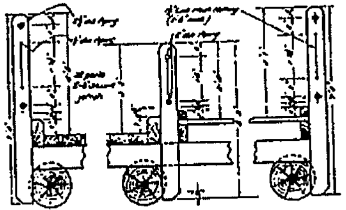
All unspliced piles and the bottom section of the spliced piles are jarrah

The top section of spliced piles is wandoo

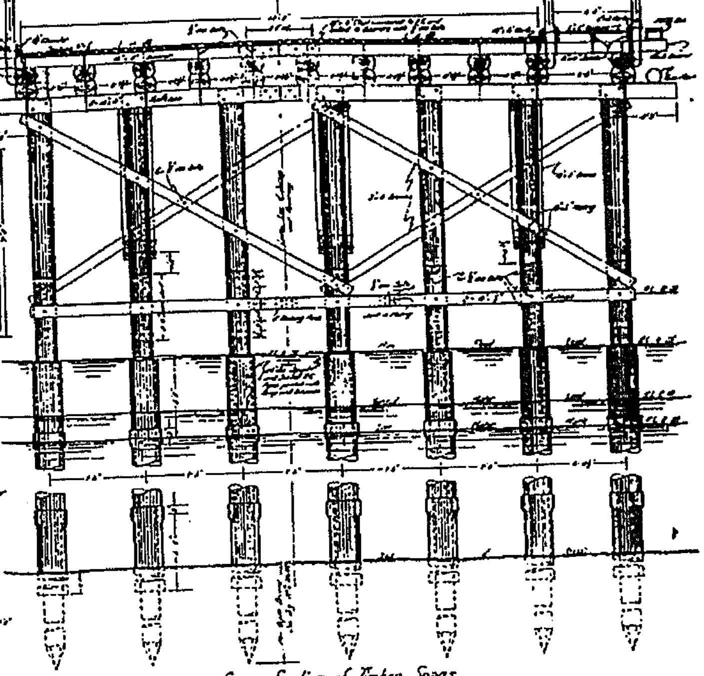
Stringers and corbels are wandoo



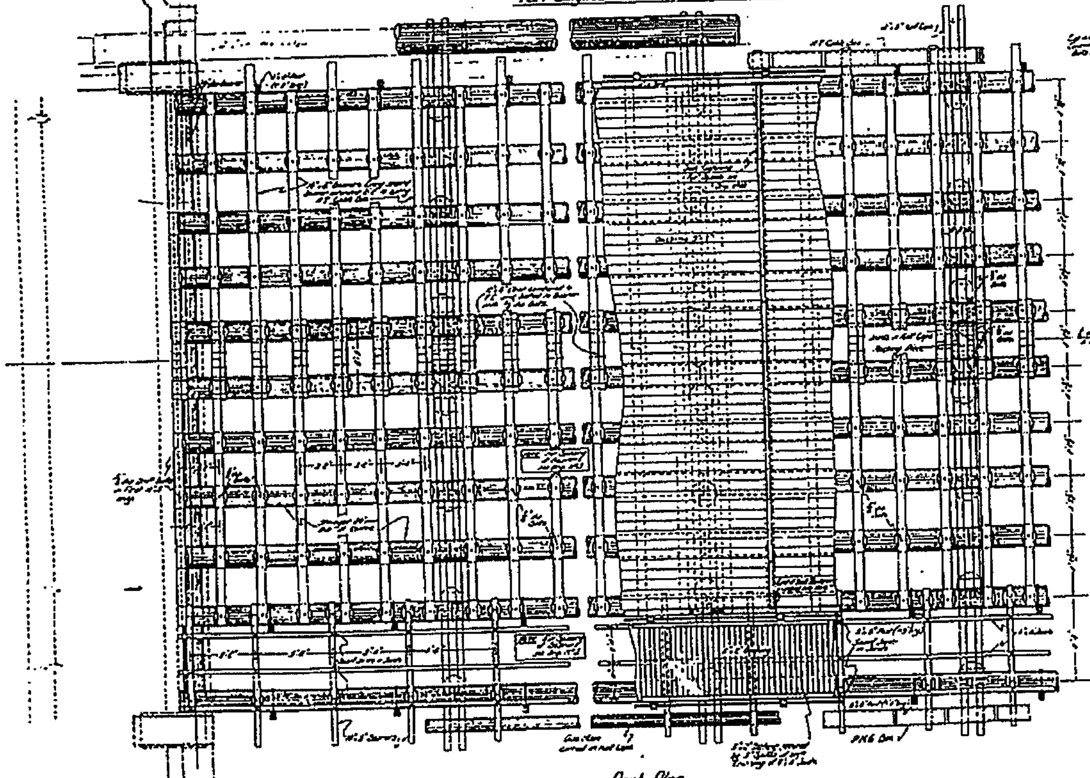
Part Longitudinal Elevation and Section.



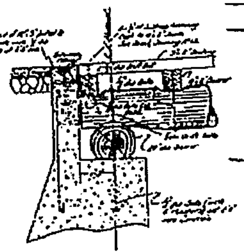
Details of Handrailing.



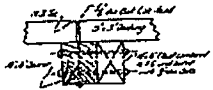
Cross Section of Timber Spans.



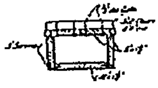
Part Plan.



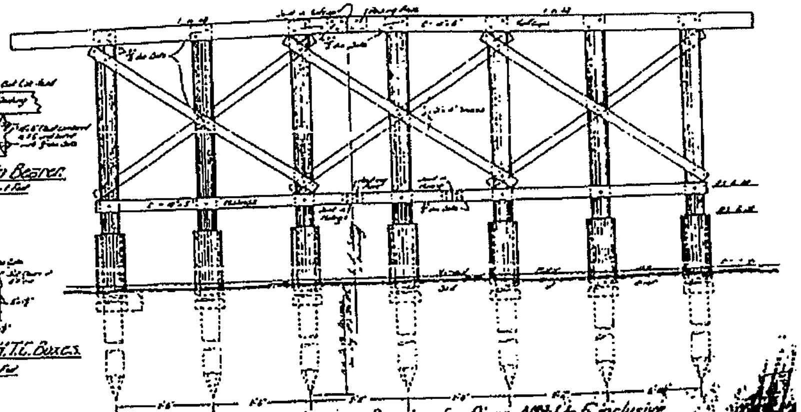
Detail at North End of Bridge.



Detail of Joint in Bearer.



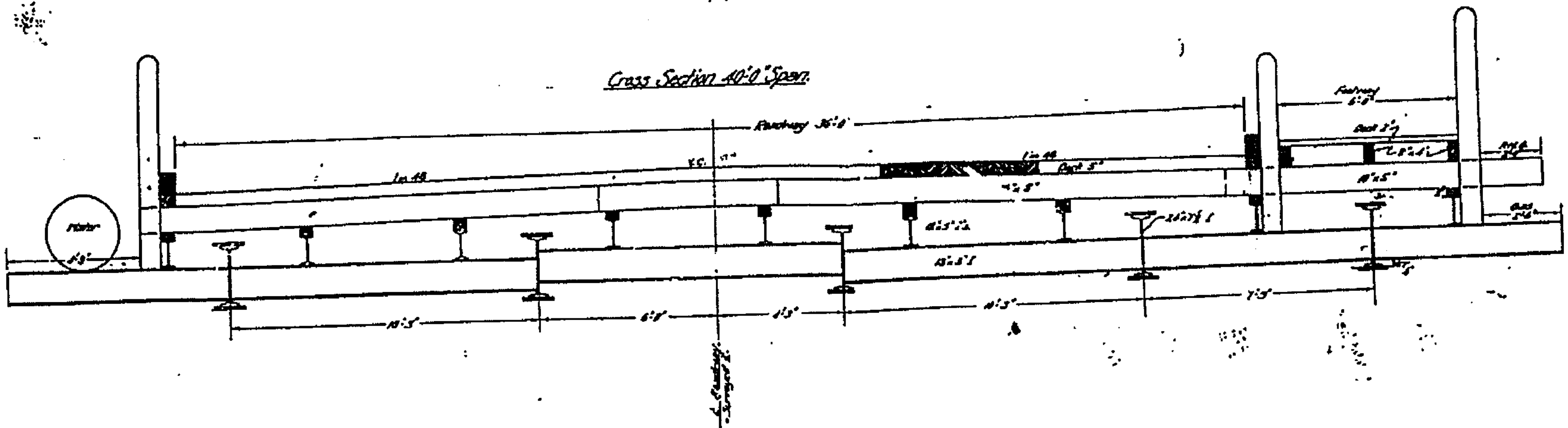
Detail of P.M.G. & A.T.C. Boxes.



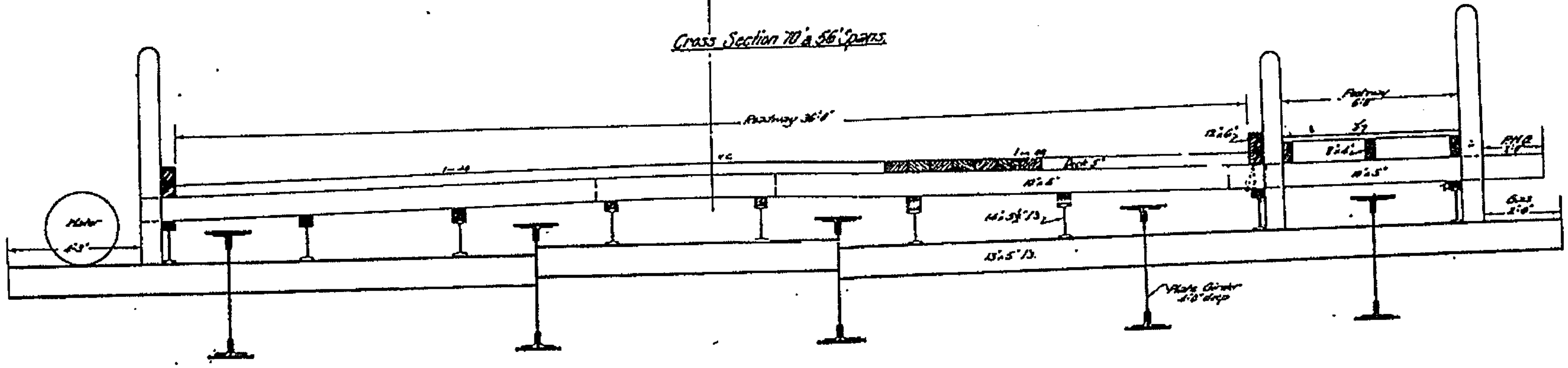
Cross Section showing Bracing for Piers Nos. 1 to 5 inclusive.

COPY OF M.R.D. W.A.

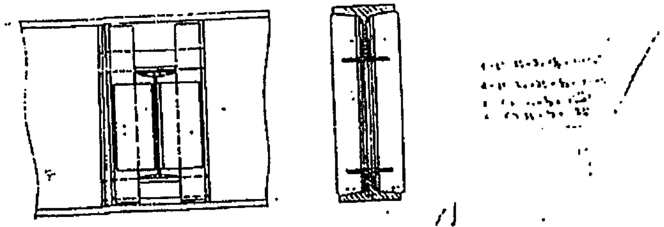
Cross Section 40'0" Span.



Cross Section 70' & 56' Spans.



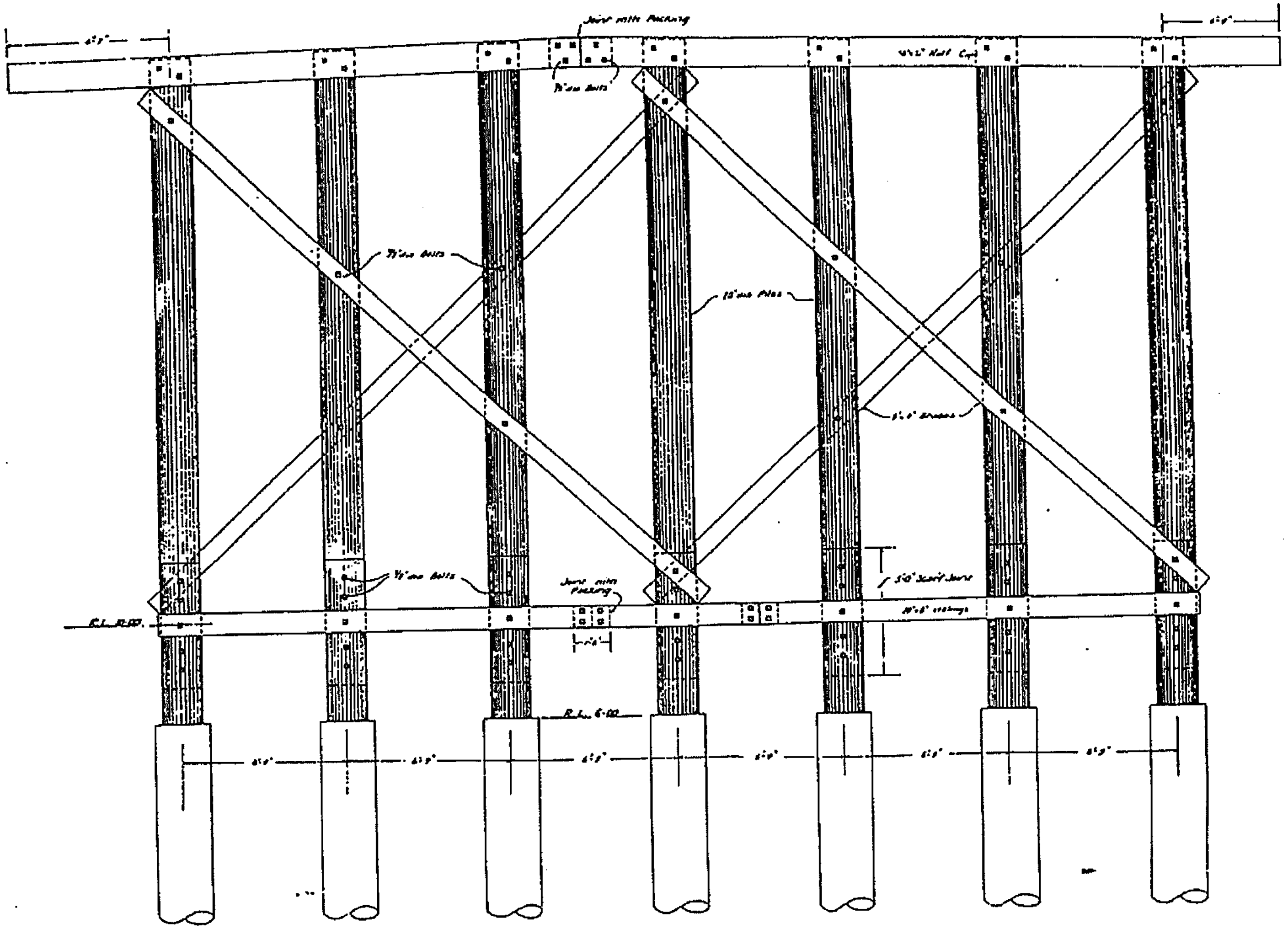
Scale. Half Inch-1 Foot.

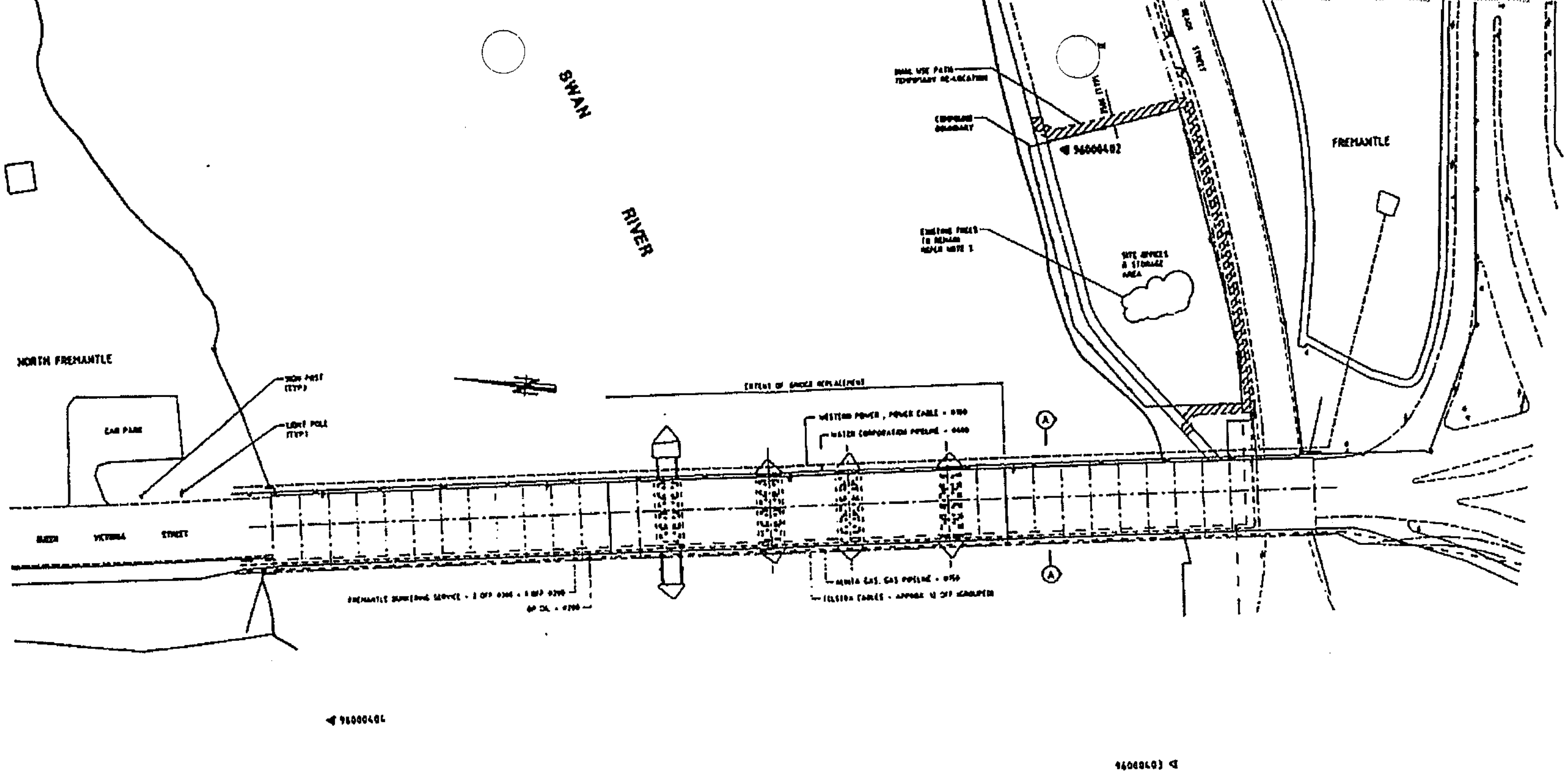


Fremantle Traffic Bridge.

Type Bracing for Piers 8 To 13. incl. and 18 to 27 Inclusive.

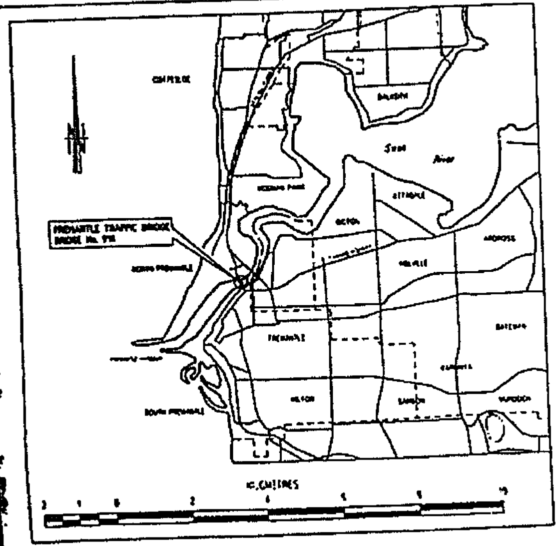
Scale 2 Feet to an Inch.



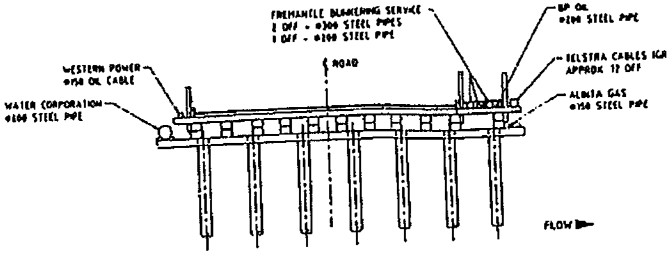


SITE PLAN
N.T.S.

SURVEY CONTROL POINTS		
SCP NAME	EASTING	NORTHING
96000401	32528 648	253531 264
96000402	32499 534	253341 667
96000403	32372 981	253304 875
96000404	32344 707	253446 448



LOCALITY PLAN



SECTION (A)
1:100

NOTE:

1. FOR GENERAL ARRANGEMENT REFER TO DRG Nº 9630-0190
2. ALL SERVICES LEADING TO AND ON THE STRUCTURE SHALL BE IDENTIFIED PRIOR TO COMMENCEMENT OF WORKS SERVICES NOT REQUIRED SHALL BE REMOVED FROM THE STRUCTURE AND CAPPED UNDER THE INSTRUCTIONS OF THE SERVICE OWNER ALL WORKS CARRIED OUT ON THE SERVICES SHALL BE DONE UNDER THE INSTRUCTIONS OF THE SERVICE OWNER
3. CONTRACTORS SITE & STORAGE COMPOUND
   - i. ACCESS TO COMPOUND SHALL BE DIRECTLY FROM BEACH STREET NOT VIA CAR PARK
   - ii. EXISTING TREES SHALL BE ENCLOSED IN PROTECTIVE FENCING, EXISTING RETICULATION PROTECTED AND GROUND RESTORATION CARRIED OUT BY ARRANGEMENT WITH FREMANTLE CITY COUNCIL
   - iii. EXISTING DUAL USE PATH SHALL BE RELOCATED TO PROVIDE CONTINUOUS ACCESS DURING CONSTRUCTION PERIOD
   - iv. EXISTING SERVICES SHALL BE PROTECTED OR TEMPORARILY RELOCATED TO ENSURE CONTINUITY OF SERVICE

28 OCT 1996

AMENDMENTS

METRO & TRAFFIC OPERATIONS

APPROVED FOR IMPLEMENTATION

ROAD TECHNOLOGY SERVICES

BRIDGE BRANCH

FILE No. 51/916 | JOB No. T307554

K. RANTANEN APR '96

J. TURNER APR. 96

J. SLATTERY MAY '96

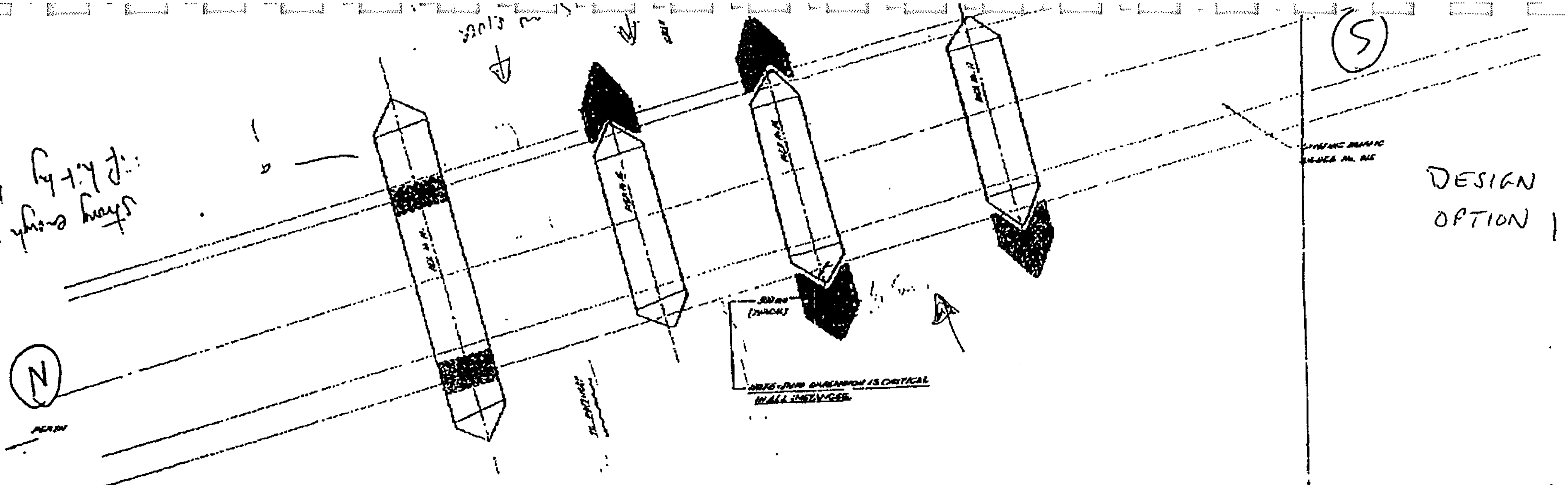
MAIN ROADS
Western Australia

FREMANTLE TRAFFIC BRIDGE
BRIDGE Nº 916 OVER SWAN RIVER
SITE & LOCALITY PLANS

116 , CITY OF FREMANTLE

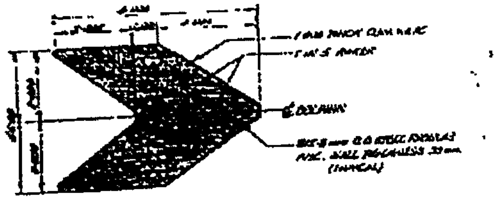
44 | 9630-0191

DESIGN OPTION 1

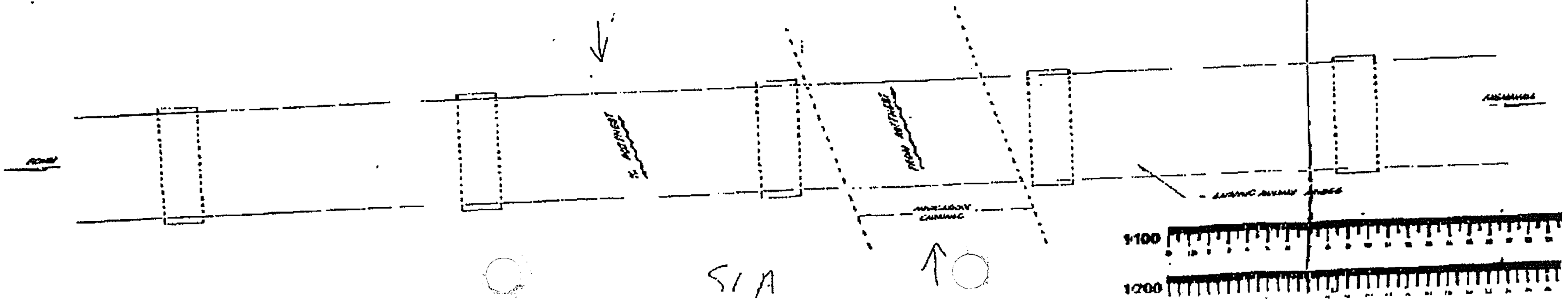


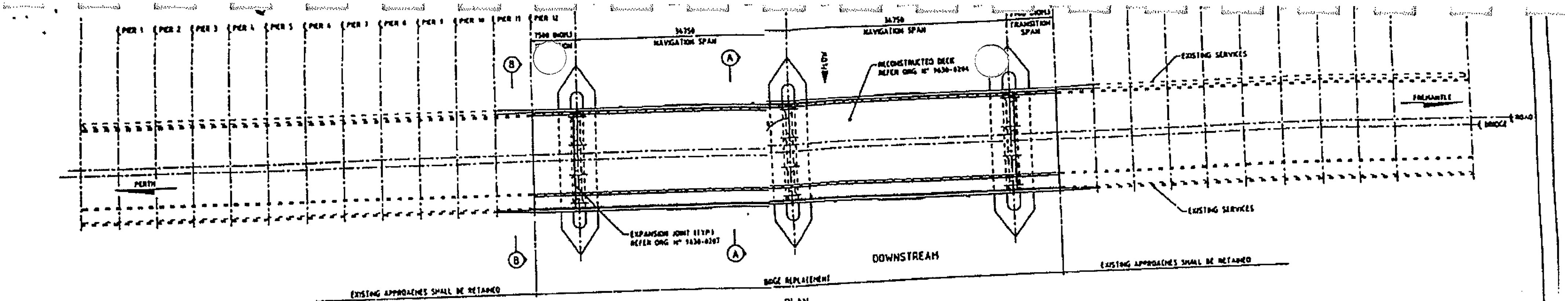
SEA

PLAN
SCALE 1:500

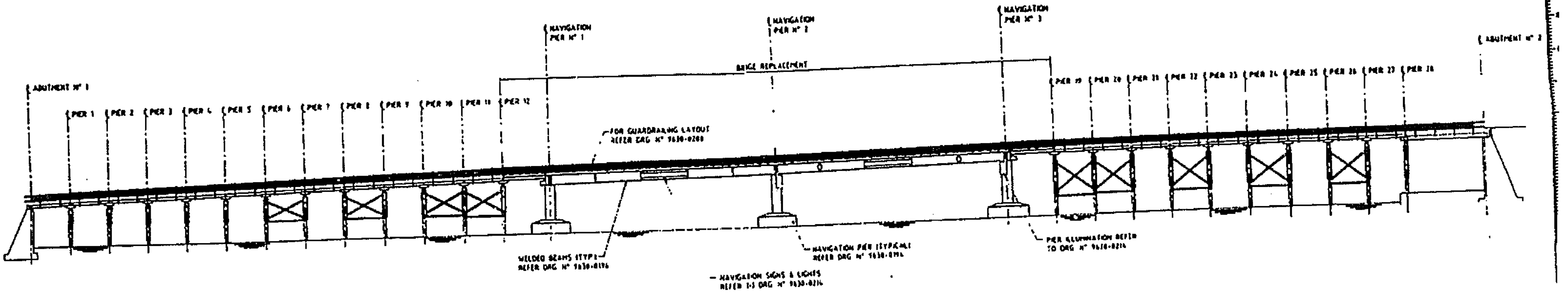


DETAIL OF TYPICAL DOLPHIN
SCALE 1:100



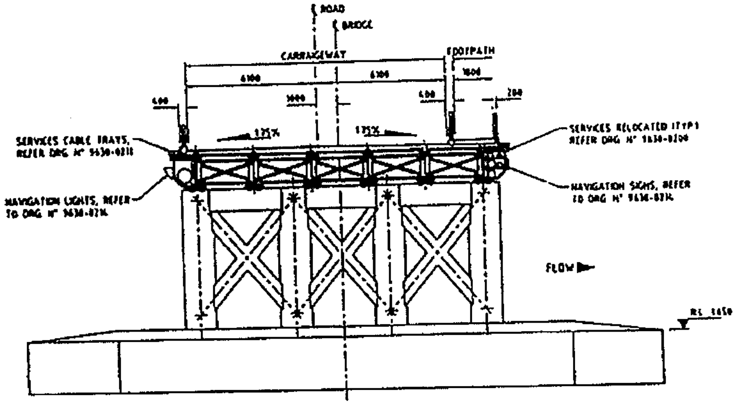


PLAN
1:250

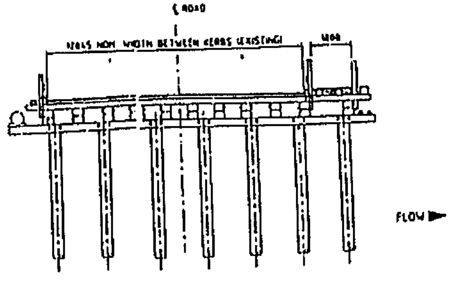


ELEVATION
1:250

SETTING OUT DETAILS
SUBSTRUCTURE - REFER DRG Nº 9630-0196
SUPERSTRUCTURE - REFER DRG Nº 9630-0204



SECTION Ⓐ
PROPOSED NAVIGATION PIERS 1, 2 & 3
1:100



SECTION Ⓑ
EXISTING PIERS 12 & 19
1:100

DESIGN INFORMATION SUMMARY

(FOR FULL DETAILS REFER DESIGN INFORMATION SHEET DRG Nº 9630-0211)

1 DESIGN IN ACCORDANCE WITH AUSTROADS BRIDGE DESIGN CODE, 1992
2 DEAD LOADS - AS PER CODE
3 TRAFFIC LOADS
    HEAVY LOAD PLATFORM - SIZE - HLP400
    LOCATION - CENTERLINE OF ROAD ±1 METRE
    OTHER - T44/L44 (6 LANES OCCUPIED)
    PEDESTRIAN LOAD - 5 kPa
4 COLLISION LOAD ON PIERS - AS PER DRG Nº 9630-0195
5 WIND SPEED
    SERVICEABILITY LS - 45 m/sec
    ULTIMATE LS - 57 m/sec
6 FLOOD DATA N/A
7 EARTHQUAKE ZONE - A
8 DIFFERENTIAL SETTLEMENT ALLOWANCE - 20 mm
9 FOUNDATION DATA - AS PER DRG Nº 9630-0195
10 CONSTRUCTION METHOD - INSITU

NOTE:

1 FOR GENERAL NOTES REFER TO DRG Nº 9630-0192
2 ALL DIMENSIONS SHOWN BEING NOMINAL SHALL BE VERIFIED BY SITE MEASUREMENT PRIOR TO FABRICATION AND CONSTRUCTION

28 OCT 1996

AMENDMENTS

METRO & TRAFFIC OPERATIONS

APPROVED FOR IMPLEMENTATION

ROAD TECHNOLOGY SERVICES

BRIDGE BRANCH

51/916	T307554
A. GIBSON JAN '96	
J. TURNER APR '96	
T. SLATTERY MAY '96	

MAIN ROADS
Western Australia

FREMANTLE TRAFFIC BRIDGE
BRIDGE Nº 916 OVER SWAN RIVER
GENERAL ARRANGEMENT

310 : CITY OF FREMANTLE

31 | 9630-0190

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	1	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 = 11m (inc current fendering) Increased length = 5.5m No. of extra glances 5.5/11 = 50% % x current glances; 0.50 x 1 = 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

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

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 6.0×10^{-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) x 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 x 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 x 95 = 380
Severe Nudge	2 x 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 x 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 x 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 1.9×10^{-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.

Design Option Input Data

DO1 Strengthening Nav Spans elongating them by 5.5m
DO2 Widening of Nav spans

4-12

V2 slightly smaller boat

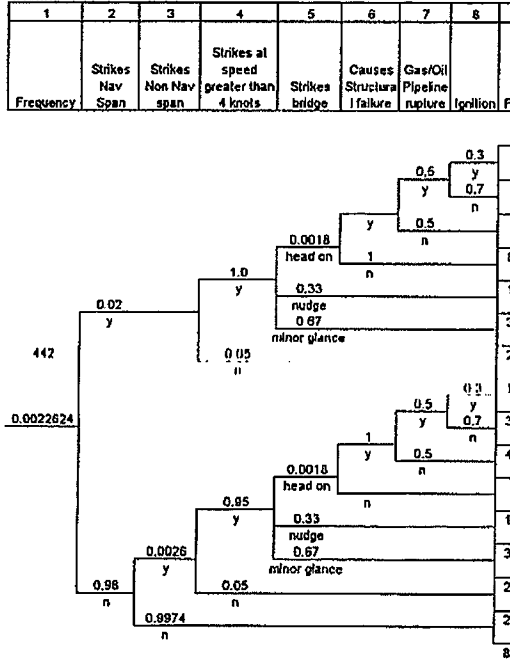
		V1	370	tonnes		V2	270	tonnes		V3	190	tonnes		V4	155
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Tree Data	1	V1 DO1 UP	V1 DO1 D	V1 DO2 UP	V1 DO2 D	V2 DO1 UP	V2 DO1 D	V2 DO2 UP	V2 DO2 D	V3 DO1 UP	V3 DO1 D	V3 DO2 UP	V3 DO2 D	V4 DO1 UP	V4 DO1 D
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	225	225	225	225	200	200
No. of people exposed on bridg	4	16	16	16	16	16	16	16	16	16	16	16	16	16	16
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	0 0018	0.0018	0.0018
Glances	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	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Causes Structural failure Nav s	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas/oil pipeline failure	13	0.5	1	0.5	1	0.5	1	0.5	1	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	0.3	0.3	0.3	0 3
Bridge fatality rate from pool &	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Boat fatality rate from jet & po	16	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5	0 25	0.5
Boat fatality rate glancing collis	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boat fatality rate sinking/decele	18	0.33	0.33	0 33	0 33	0.2	0.2	0 2	0 2	0 2	0 2	0 2	0 2	0 33	0 33

Design Option Input Data

								Boats smaller			
		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	V5 DO1 UP	V5 DO1 D	V5 DO2 UP	V5 DO2 D	V6 DO1 UP	V6 DO1 D	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	7.40E-04	7.40E-04	7.40E-04	7.40E-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	16	16	16	16	16	16	16	16	16	16
Strikes Nav 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	0.0018	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	0	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	1	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 &	15	1	1	1	1	1	1	1	1	1	1
Boat fatality rate from jet & po	16	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5
Boat fatality rate glancing collis	17	0	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	0.2	0.2

Event tree for passage through Fremantle Bridge
Boat Name : Vessel 1
Code V1 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening
Upstream of bridge, travelling into the harbour

Events



People exposed on bridge

Immediate

People exposed on boat

Consequences Bridge

Consequences Boat

9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure on bridge	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure on boat	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
				16			320			320			320				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	80					0.33	106		201.6		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	108		105.6		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	108		105.6		
8.12E-08	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106	8 58E-06	105 6	8 58E-06	8 12E-08
1.50E-05	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
3.00E-05	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
2 38E-06	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
1.48E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	[illegible]	0.25	80	[illegible]				0.33	106	[illegible]	201.6	4 87E-07	1 48E-09
3.45E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	108	3.64E-07	105 6	3.64E-07	3 45E-09
4.92E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	108	5.20E-07	105.6	5.20E-07	4.92E-09
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106		105 6		
1.82E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
3.64E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
2.88E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
2.21E-03	Boat passes under bridge	f															
8.47E-08																	

Check sum 2.26E-03
cool

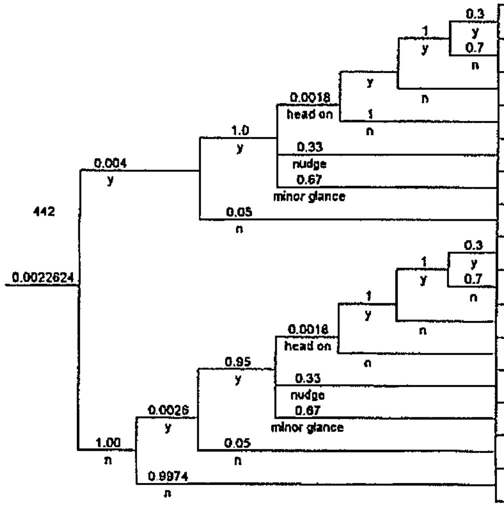
Total PLL 9.85E-06

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 : 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 | Immediate | People exposed on boat

Events | Consequences Bridge | Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			320			320			320				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	160					0.33	106		281.6		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	108		105.6		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	108		105.6		
								1.55E-08	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	108	1 63E-08	105 6	1 63E-08	1.55E-08
								2.86E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								5.72E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								4.52E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								3.01E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	1.12E-07	0.5	160	1.12E-06				0.33	106	3.17E-07	281.6	1.55E-06	3.01E-09
								7.01E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106	7.41E-07	105.6	7.41E-07	7.01E-09
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	108		105 8		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	108		105 6		
								1.85E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								3.70E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								2.93E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								2.25E-03	Boat passes under bridge	f															
								2.25E-08																	
							Check sum	2.26E-03																	
								cool																	

Total PLL 3.93E-06

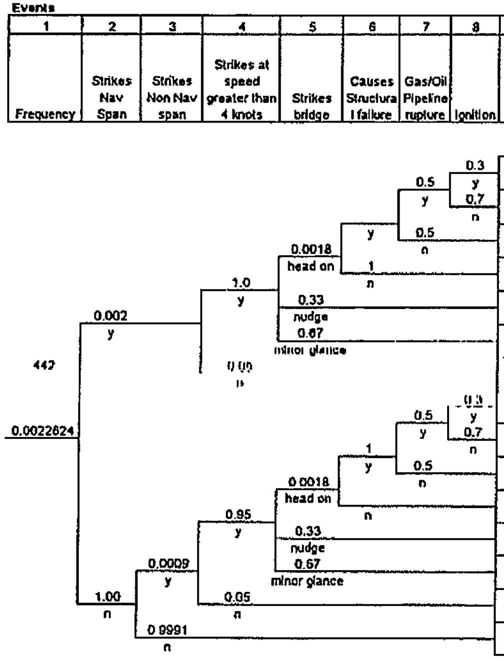
Outcomes

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 : Vessel 1
Code V1 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure on bridge	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure on boat	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No of fatalities	22 Total PLL	23 Freq
				16			320			320			320				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	80					0.33	106		201.6		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106		105.6		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106		105.6		
7.35E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106	7.76E-07	105.6	7.76E-07	7.35E-09
1.36E-08	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
2.72E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
[illegible]	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
5.02E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	[illegible]	0.25	80	[illegible]				0.33	106	[illegible]	201.6	[illegible]	[illegible]
1.17E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106	1.24E-07	105.6	1.24E-07	1.17E-09
1.67E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106	1.77E-07	105.6	1.77E-07	1.67E-09
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106		105.6		
6.19E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
1.24E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
9.79E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
2.26E-03	Boat passes under bridge	f															

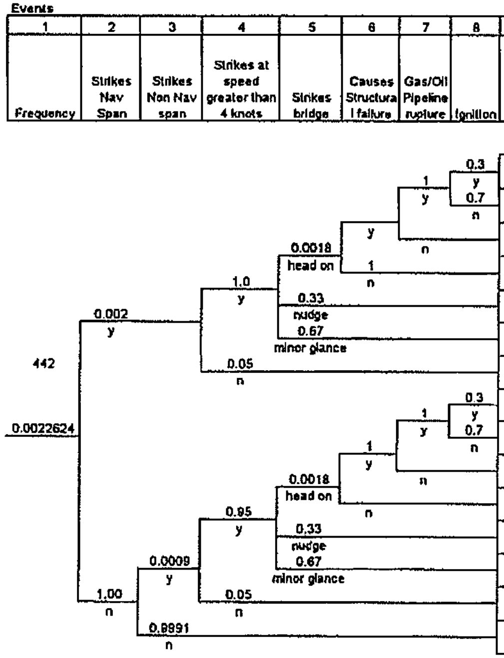
8.52E-09
Check sum 2.26E-03
cool

Total PLL 1.24E-06

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 : Vessel 1
Code V1 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

Events



People exposed on bridge — Consequences Bridge (12–14)
Consequences Boat — Immediate — People exposed on boat

9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			320			320			320				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	160					0.33	106		281.6		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106		105.6		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106		105.6		
7.35E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106	7.76E-07	105.6	7.76E-07	7.35E-09
1.36E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
2.72E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
2 15E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
1.00E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	3.75E-08	0.5	160	3.75E-07				0.33	106	1.06E-07	281.6	5.18E-07	1.00E-09
2.34E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106	2.47E-07	105.6	2.47E-07	2.34E-09
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 33	106		105.6		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	106		105 6		
6.19E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
1.24E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
9.79E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
2.28E-03	Boat passes under bridge	f															
8.69E-09																	

Check sum 2.28E-03
cool

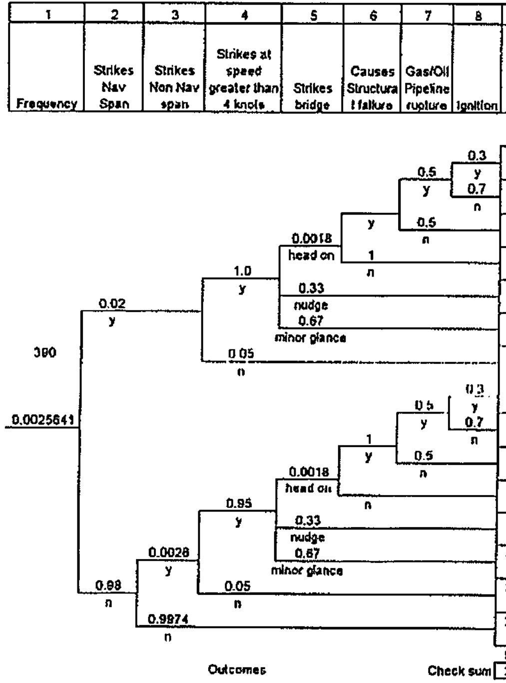
Total PLL 1.54E-08

Outcomes

- 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 : Vessel 2
Code V2 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening
Upstream of bridge, travelling into the harbour

Events



People exposed on bridge

Immediate

People exposed on boat

Consequences Bridge

Consequences Boat

9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			210			210			210				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	52.5					0.2	42		110.5		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
9.21E-08	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42	3.87E-06	42	3.87E-06	9 21E-08
1.70E-05	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
3.40E-05	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
2 09E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
1 67E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	0 25E 08	0 25	52 5	2 09E 07				0 2	42	7 01E 08	110 5	3 38E 07	1 67E 09
3.91E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42	1 64E-07	42	1 64E-07	3.91E-09
5.58E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42	2 34E-07	42	2 34E-07	5 58E-09
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
2.06E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
4.13E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
3.26E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
2.50E-03	Boat passes under bridge	f															
9.60E-08																	
2.56E-03																	
cool																	

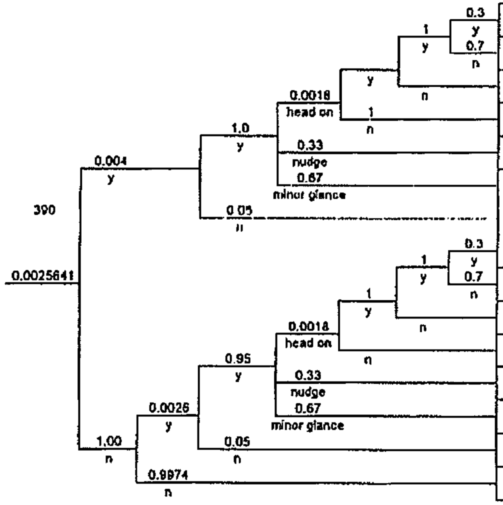
Total PLL 4.60E-06

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 : 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
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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
												18			210			210			210				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	18		0.5	105					0.2	42		163		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
								1.75E-08	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42	7 37E-07	42	7 37E-07	1 75E-08
								3.24E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								6.48E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								5 13E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								3.41E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	18	1 27E-07	0.5	105	8.35E-07				0 2	42	1 43E-07	163	1 10E-06	3 41E 09
								7.95E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42	3.34E-07	42	3.34E-07	7.95E-09
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
								2.10E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								4.20E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								3.32E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								2.55E-03	Boat passes under bridge	f															

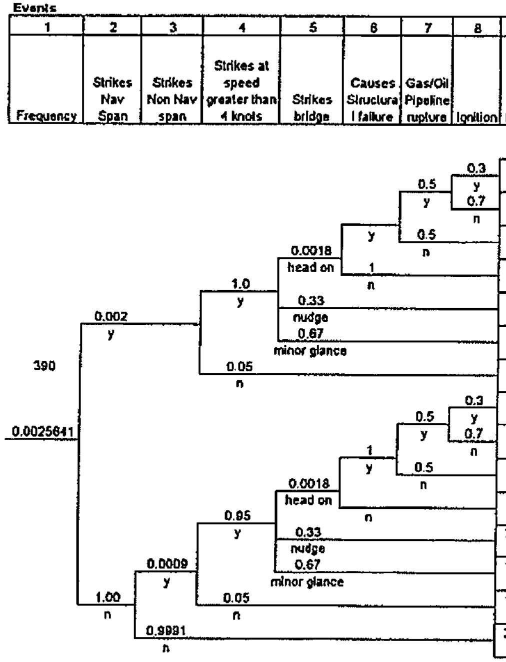
2.55E-08
Outcomes Check sum 2 56E-03
cool

Total PLL 2.18E-08

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 : Vessel 2
Code V2 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

Events



People exposed on bridge
Immediate
People exposed on boat

Consequences Bridge
Consequences Boat

9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			210			210			210				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	52.5					0.2	42		110 5		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
8.33E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	42	3.50E-07	42	3.50E-07	8.33E-09
1.54E-08	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
3.08E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
2.44E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
5.69E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	2.12E-08	0.25	52.5	6 97E-08				0 2	42	2.39E-08	110.5	1.15E-07	5.69E-10
1.33E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42	5.58E-08	42	5.58E-08	1.33E-09
1.90E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	42	7 96E-08	42	7.96E-08	1.90E-09
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
7.01E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
1.40E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
1.11E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
2.56E-03	Boat passes under bridge	f															

9.86E-09

Outcomes Check sum 2.56E-03
cool

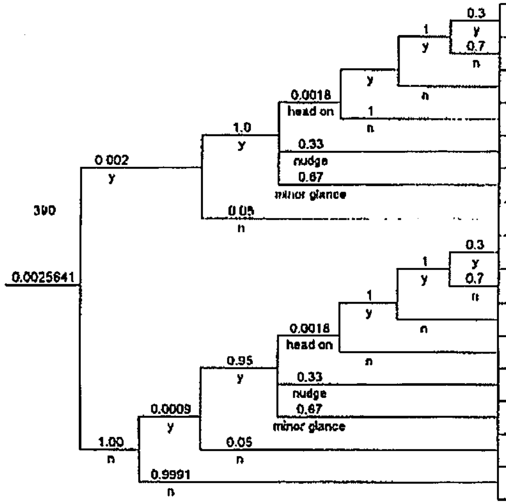
Total PLL 6.00E-07

a	Natural gas / Oil pipeline
b	Head on colison > 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 : 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
Immediate

Events
Consequences Bridge
Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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
												18			210			210			210				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	18		0.5	105					0.2	42		163		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
								8.33E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	42	3 50E-07	42	3 50E-07	8 33E-09
								1.54E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								3.08E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								2 44E 07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								1.14E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	18	4.25E-08	0.5	105	2 79E-07				0 2	42	4 78E-08	163	3 69E-07	1.14E-09
								2.65E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42	1.12E-07	42	1.12E-07	2 65E-09
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	42		42		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	42		42		
								7.01E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								1.40E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								1.11E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								2.56E-03	Boat passes under bridge	f															
								1.10E-08																	
						Check sum		2.56E-03															Total PLL	8.30E-07	
								cool																	

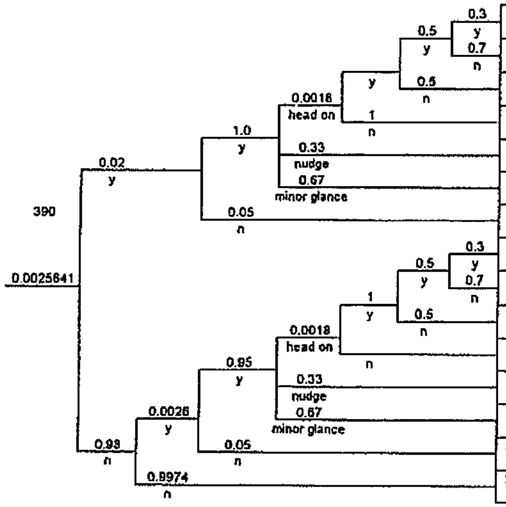
Outcomes

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

People exposed on boat
People exposed on bridge
Immediate

Events
Consequences Bridge
Consequences Boat



1 Frequency	2 Strikes Nav Span	3 Strikes Non Nav span	4 Strikes at speed greater than 4 knots	5 Strikes bridge	6 Causes Structural failure	7 Gas/Oil Pipeline rupture	8 Ignition	9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure on bridge	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure on boat	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
												16			225			225			225				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	56.25					0.2	45		117.25		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
								9.21E-08	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45	4 14E-08	45	4 14E-06	9.21E-08
								1.70E-05	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								3.40E-05	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								2.89E-06	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								1.67E-09	Pipeline ruptures (NG or WO) Fatalities from jet,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	1.67E-09
								3.91E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45	1.76E-07	45	1.76E-07	3.91E-09
								5.58E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45	2 51E-07	45	2 51E-07	5.58E-09
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	45		45		
								2.06E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								4.13E-08	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								3.26E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								2.50E-03	Boat passes under bridge	f															

9.00E-08
Check sum 2.56E-03
cool

Outcomes

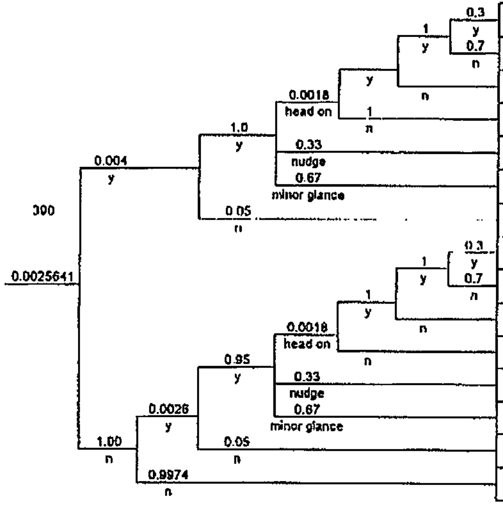
Total PLL 4.93E-06

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 : Vessel 3
Code V3 001 0
Design Option 1 Addition of dolphins and fender strengthening
Downstream of bridge, travelling from the harbour

Events

1	2	3	4	5	6	7	8
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition



People exposed on bridge — Consequences Bridge
Consequences Boat — Immediate — People exposed on boat

9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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
				18			225			225			225				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	18		0.5	112.5					0 2	45		173.5		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
1.75E-08	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	45	7 89E-07	45	7.89E-07	1 75E-08
3.24E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
6.48E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
5 13E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
3 41E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	18	1 27E-07	0 5	112 5	0 94E-07				0 2	45	1 03E-07	173 5	1 17E-06	3 41E-09
7.95E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45	3 58E-07	45	3 58E-07	7.95E-09
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	45		45		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
2.10E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
4.20E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
3.32E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
2.55E-03	Boat passes under bridge	f															
2.55E-08																	

Outcomes

Check sum 2.56E-03
cool

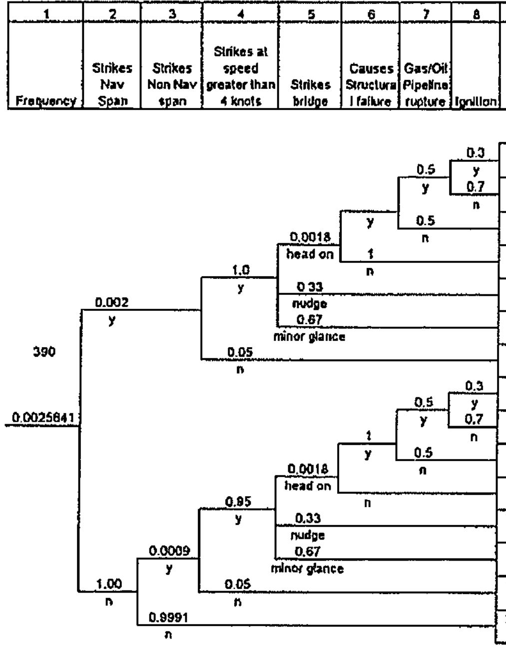
Total PLL 2.32E-06

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 : Vessel 3
Code V3 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			225			225			225				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	56.25					0.2	45		117.25		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
8.33E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45	3 75E-07	45	3 75E-07	8.33E-09
1.54E-08	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
3.08E-08	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
2.44E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
5.69E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	2.12E-08	0.25	56.25	7.47E-08				0.2	45	2.56E-08	117.25	1 22E-07	5.69E-10
1.33E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45	5 97E-08	45	5 97E-08	1,33E-09
1.90E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45	8 53E-08	45	8.53E-08	1 90E-09
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
7.01E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
1.40E-08	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
1.11E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
2.56E-03	Boat passes under bridge	f															

9.66E-09
Check sum 2.56E-03
cool

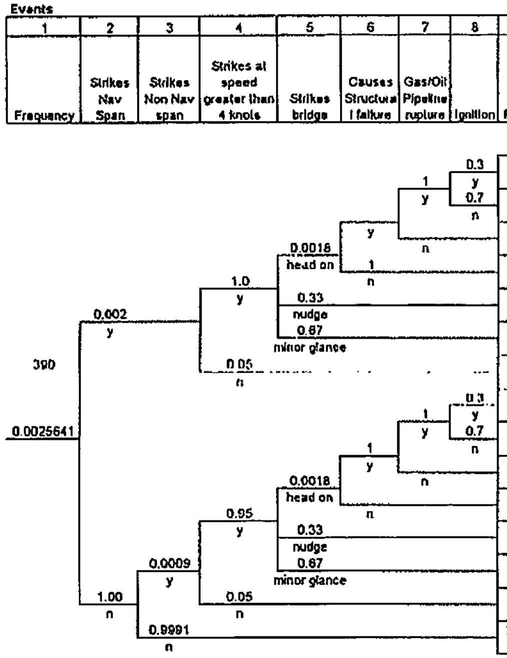
Total PLL 6.41E-07

Outcomes

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 : Vessel 3
Code V3 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

Events



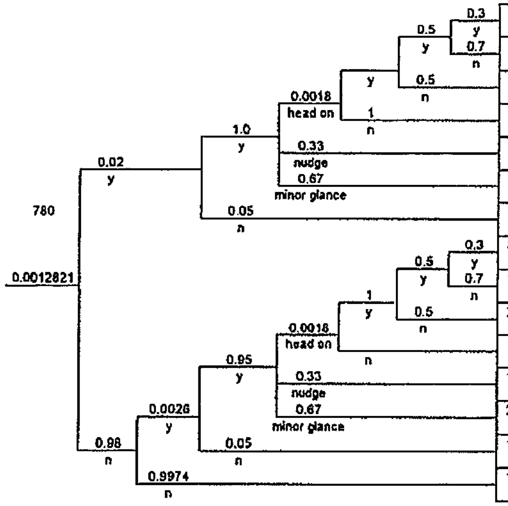
			Consequences Bridge			Consequences Boat											
				People exposed on bridge					Immediate		People exposed on boat						
9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			225			225			225				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	112.5					0.2	45		173.5		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
8.33E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45	3.75E-07	45	3.75E-07	8.33E-09
1.54E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
3.08E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
2.44E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
1.14E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	[illegible]	0.5	112.5	[illegible]				0.2	45	[illegible]	173.5	[illegible]	1.14E-09
2.65E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45	1.19E-07	45	1.19E-07	2.65E-09
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	45		45		
7.01E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
1.40E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
1.11E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
2.56E-03	Boat passes under bridge	f															
1.10E-08																	
Check sum 2.56E-03															Total PLL	8.87E-07	
cool																	

a	Natural gas / Oil pipeline
b	Head on colison > 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 : **Vessel 4**
Code **V4 DD1 UP**
Design Option 1 **Addition of dolphins and fender strengthening**
Upstream of bridge, travelling into the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



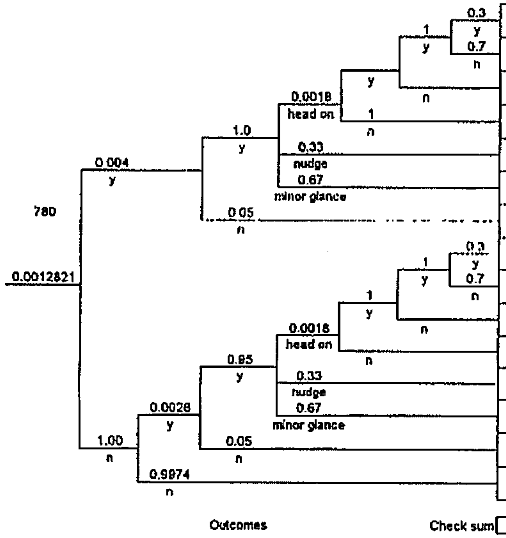
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			200			200			200				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	50					0 33	66		132		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	68		66		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66		68		
								4.60E-08	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66	3 04E-08	68	3.04E-08	4.60E-08
								8.51E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								1.70E-05	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								1.35E-06	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								8.37E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	3.12E-08	0.25	50	9.77E-08				0.33	68	5.52E-08	132	1.84E-07	8.37E-10
								1.95E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66	1.29E-07	66	1.29E-07	1.95E-09
								2.79E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	68	1.84E-07	68	1.84E-07	2 79E-09
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 33	68		68		
								1,03E-08	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								2.06E-08	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								1.63E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								1.25E-03	Boat passes under bridge	f															
								4.80E-08																	
	Outcomes						Check sum	1.28E-03															Total PLL	3.54E-08	
								cool																	

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 : Vessel 4
Code V4 DO1 D
Design Option 1 Addition of dolphins and fender strengthening
Downstream of bridge, travelling from the harbour

Events

1	2	3	4	5	6	7	8
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition



People exposed on bridge — Immediate — People exposed on boat

Consequences Bridge — Consequences Boat

9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			200			200			200				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	100					0.33	66		182		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66		68		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	68		66		
8.77E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 33	66	5.70E-07	66	5 79E-07	8.77E-09
1.62E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
3,24E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
2 50E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
1.70E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	0.36E-08	0 5	100	3 07E 07				0 33	66	1 12E-07	182	5 73E-07	1 70E 09
3 97E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66	2 62E-07	66	2 62E-07	3 07E-09
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66		66		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66		66		
1.05E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
2.10E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
1.66E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
1.27E-03	Boat passes under bridge	f															
1.27E-08																	

Check sum 1.28E-03
cool

Total PLL 1.41E-08

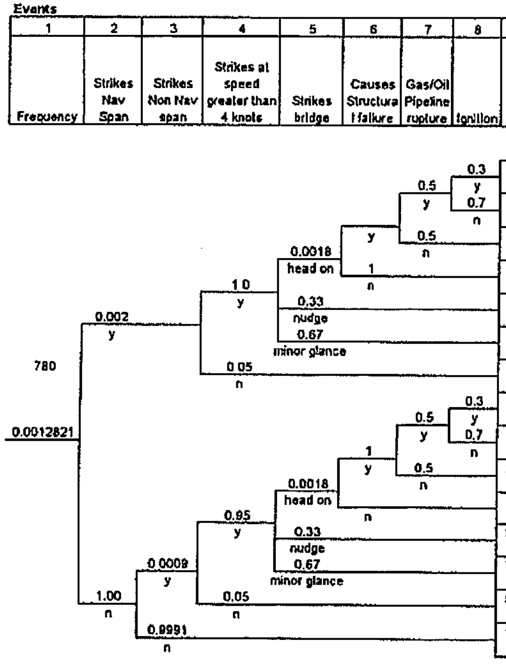
a	Natural gas / Oil pipeline
b	Head on collison > 8 knots
c	Nudging collision > 8 knots
d	Glancing collision > 8 knots
e	Severe glancing impact onto structure. LOP
f	Straight through

Event tree for passage through Fremantle Bridge
Boat Name : Vessel 4
Code V4 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

People exposed on bridge
Immediate
People exposed on boat

Events

Consequences Bridge
Consequences Boat



9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No of fatalities	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			200			200			200				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	50					0.33	66		132		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66		66		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66		66		
4.17E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66	2.75E-07	66	2.75E-07	4 17E-09
7.70E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
1.54E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
1.22E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
2.84E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	1.06E-08	0.25	50	3.32E-08				0.33	66	1.88E-08	132	6.26E-08	2.84E-10
6.64E-10	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 33	66	4.38E-08	66	4.38E-08	6.64E-10
9.48E-10	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66	6.26E-08	66	6.26E-08	9.48E-10
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66		66		
3.51E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
7.01E-07	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
5.55E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
1.28E-03	Boat passes under bridge	f															
4.83E-09																	

Outcomes

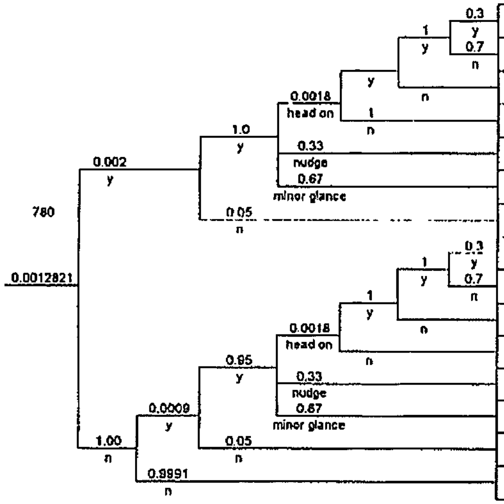
Check sum 1.28E-03
cool

Total PLL 4.44E-07

- 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 : Vessel 4
Code V4 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

Events



											Consequences Bridge People exposed on bridge			Consequences Boat			Immediate			People exposed on boat					
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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			200			200			200				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	100					0.33	66		182		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 33	66		66		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66		66		
								4.17E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 33	66	2 75E-07	66	2 75E-07	4 17E-09
								7.70E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								1.54E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								1 22E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								5 69E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	2 12E-08	0.5	100	1 33E-07				0 33	66	3 75E-08	182	1 92E-07	5 69E-10
								1.33E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.33	66	8 76E-08	66	8 76E-08	1 33E-09
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 33	66		66		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 33	66		66		
								3.51E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								7.01E-07	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								5.55E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								1.28E-03	Boat passes under bridge	f															
								5.49E-09																	
							Check sum	1.28E-03																	
								cool																	

Total PLL 5.54E-07

Outcomes

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 : Vessel 5
Code V5 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening
Upstream of bridge, travelling into the harbour

People exposed on bridge

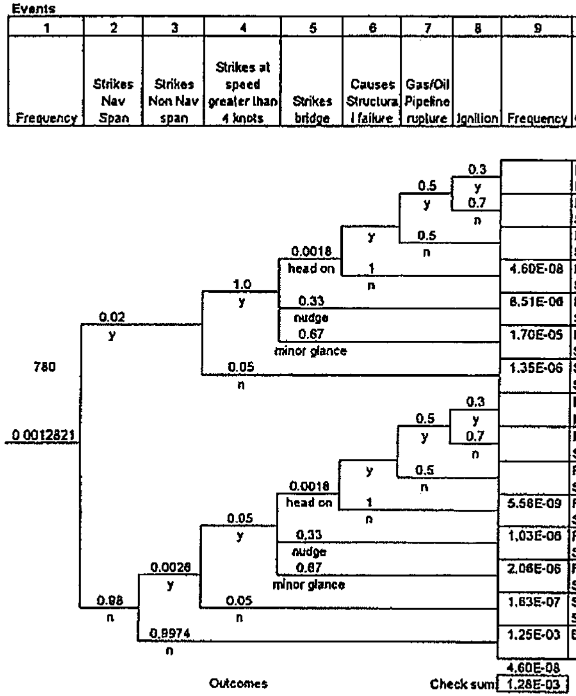
Immediate

People exposed on boat

Events

Consequences Bridge

Consequences Boat



9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure on bridge	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure on boat	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
				16			142			142			142				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	35.5					0.2	28		79.9		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
4.60E-08	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28	1.31E-06	28 4	1.31E-06	4.60E-08
8.51E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
1.70E-05	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
1.35E-06	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	35.5					0.2	28		79.9		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28 4		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28 4		
5.58E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28	1.58E-07	28 4	1.58E-07	5.58E-09
1.03E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
2.06E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
1.63E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
1.25E-03	Boat passes under bridge	f															
4.60E-08																	
Check sum 1.28E-03																	
cool																	

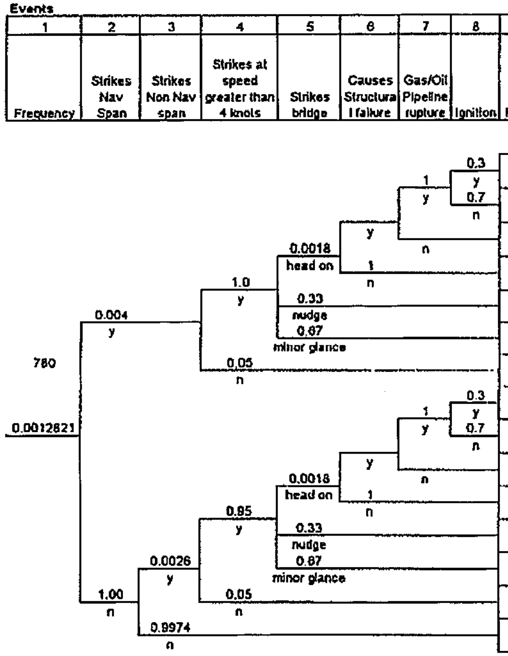
Total PLL 1.47E-08

Outcomes

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 : Vessel 5
Code V5 DO1 D
Design Option 1 Addition of dolphins and fender strengthening
Downstream of bridge, travelling from the harbour

Events



People exposed on bridge

Immediate

People exposed on boat

Consequences Bridge

Consequences Boat

9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure on bridge	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure on boat	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
				16			142			142			142				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0,5	71					0.2	28		115.4		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
8.77E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28	2 40E-07	28 4	2 49E-07	8 77E-09
1.62E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
3.24E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
2 50E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	71					0.2	28		115 4		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	28		28.4		
5.68E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28	1.61E-07	28.4	1.61E-07	5,68E-09
1.05E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
2.10E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
1.66E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
1,27E-03	Boat passes under bridge	f															
8.77E-09																	

Outcomes

Check sum 1.28E-03
cool

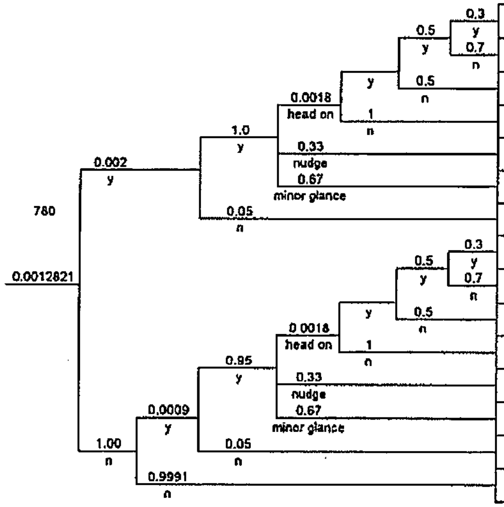
Total PLL 4.10E-07

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 : Vessel 5
Code V5 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

Events

1	2	3	4	5	6	7	8
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition



People exposed on bridge
Immediate
People exposed on boat

Consequences Bridge **Consequences Boat**

9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No of fatalities	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
				18			142			142			142				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	35.5					0.2	28		79.9		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
4.17E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	28	1 18E-07	28.4	1.18E-07	4.17E-09
7.70E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
1.54E-08	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
1.22E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	35.5					0.2	28		79 9		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
1.90E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28	5.39E-08	28.4	5.39E-08	1.90E-09
3.51E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
7.01E-07	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
5.55E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
1.28E-03	Boat passes under bridge	f															

4.17E-09
Check sum 1.28E-03
cool

Total PLL 1 72E-07

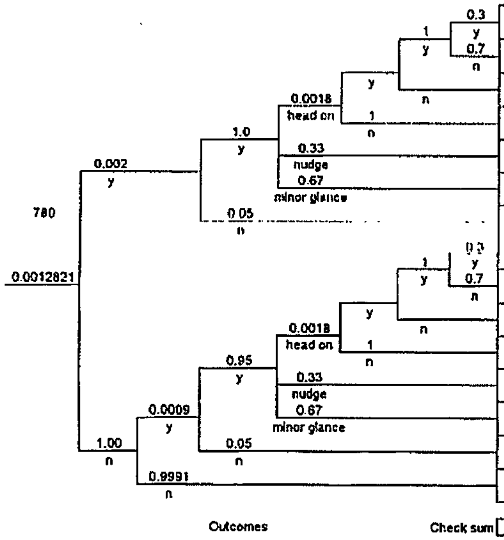
Outcomes

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 : Vessel 6
Code V5 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No of fatalities	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			142			142			142				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	71					0 2	28		115 4		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28		28.4		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	28		28 4		
								4.17E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	28	1 18E-07	28 4	1 18E-07	4 17E-09
								7.70E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								1.54E-08	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								1 22E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	71					0 2	28		115 4		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	28		28 4		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	28		28 4		
								1.90E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	28	5 39E-08	28.4	5.39E-08	1.90E-09
								3.51E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								7.01E-07	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								5.55E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								1.28E-03	Boat passes under bridge	f															

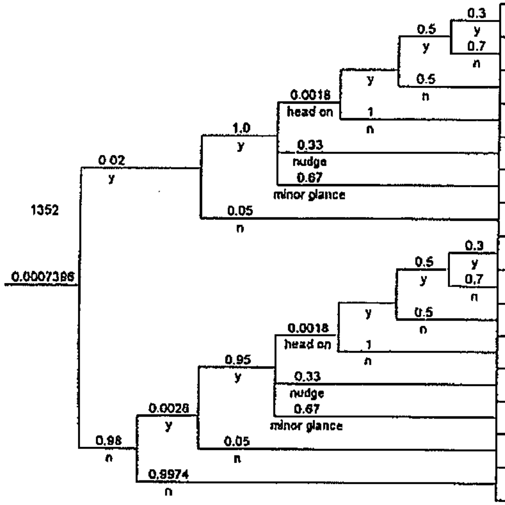
4.17E-09
Check sum 1.28E-03
cool

Total PLL 1.72E-07

a	Natural gas / Oil pipeline
b	Head on colison > 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 : Vessel 6
Code V6 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening
Upstream of bridge, travelling into the harbour

Events



People exposed on bridge — Consequences Bridge
Consequences Boat — Immediate — People exposed on boat

1 Frequency	2 Strikes Nav Span	3 Strikes Non Nav span	4 Strikes at speed greater than 4 knots	5 Strikes bridge	6 Causes Structural failure	7 Gas/Oil Pipeline rupture	8 Ignition	9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure on bridge	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure on boat	16 No of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
												16			119.4			119.4			119				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	29 85					0.2	24		69.73		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
								2.66E-08	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	24	6 34E-07	23.88	6 34E-07	2 66E-08
								4.91E-06	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								9.82E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								7.77E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	20.85					0.2	24		69.73		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	24		23.88		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
								3.22E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24	7.69E-08	23.88	7 69E-08	3.22E-09
								5.95E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								1.19E-08	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								9.41E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								7.22E-04	Boat passes under bridge	f															

2.66E-08
Check sum 7.40E-04
cool

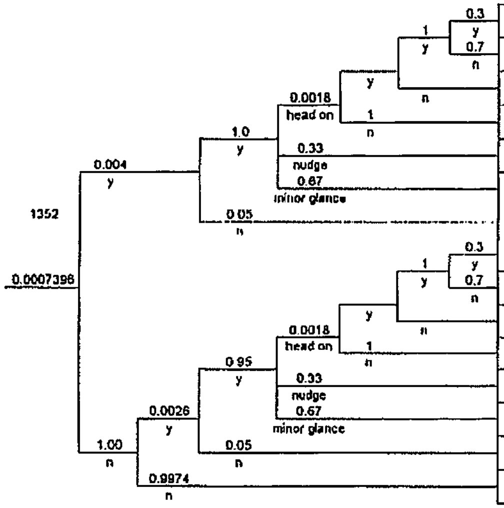
Total PLL 7.11E-07

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 : Vessel 8
Code V8 DO1 D
Design Option 1 Addition of dolphins and fender strengthening
Downstream of bridge, travelling from the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			119.4			119.4			119				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	59.7					0.2	24		99.58		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
								5.06E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24	1.21E-07	23.88	1.21E-07	5.08E-09
								9.35E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								1.87E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								1.48E-07	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	59.7					0.2	24		99.58		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
								3.28E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24	7.82E-08	23.88	7.82E-08	3.28E-09
								6.05E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								1.21E-06	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								9.58E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								7.35E-04	Boat passes under bridge	f															
								5.06E-09																	
							Check sum	7.40E-04																	
								cool																	

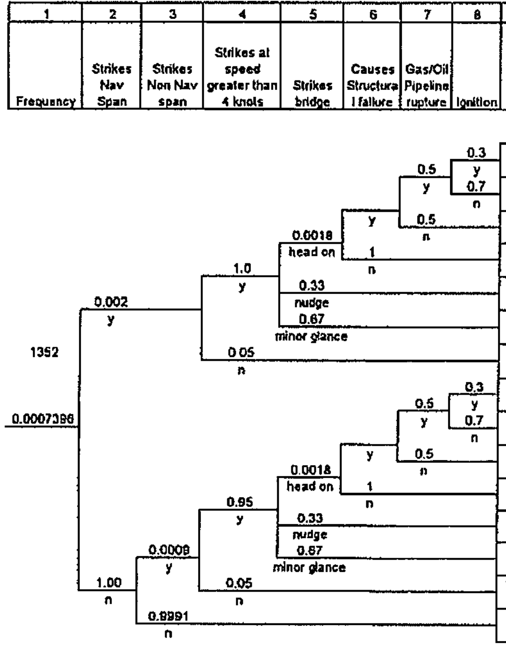
Outcomes

Total PLL 1.99E-07

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 : Vessel 6
Code V6 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

Events



People exposed on bridge

Immediate

People exposed on boat

Consequences Bridge

Consequences Boat

9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure on bridge	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure on boat	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
				16			119.4			119.4			119				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	29.85					0.2	24		69.73		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23 88		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
2.40E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0 2	24	5 74E-08	23 88	5.74E-08	2.40E-09
4.44E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
8.88E-07	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
7.03E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	29.85					0.2	24		69 73		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23 88		
1.09E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24	2.81E-08	23.88	2 81E-08	1 09E-09
2.02E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
4.04E-07	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
3.20E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
7.38E-04	Boat passes under bridge	f															

2.40E-09
Check sum 7.40E-04
cool

Total PLL 8.35E-08

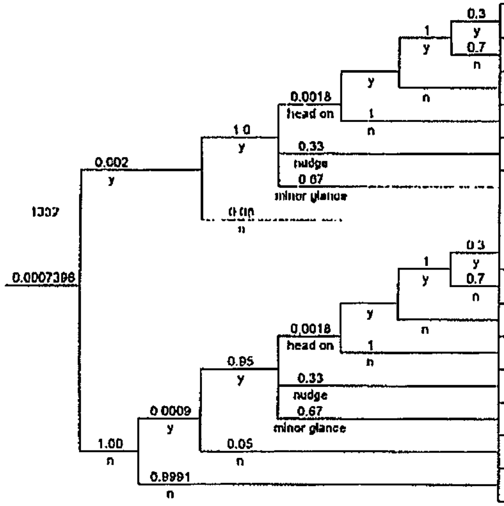
a Natural gas / Oil pipeline
b Head on colison > 8 knots
c Nudging collision > 8 knots
d Glancing collision > 8 knots
e Severe glancing impact onto structure. LOP
f Straight through

Event tree for passage through Fremantle Bridge
Boat Name : Vessel 6
Code V6 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

People exposed on boat
People exposed on bridge
Immediate

Events
Consequences Bridge
Consequences Boat

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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality Rate from pool and jet fire exposure on bridge	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure on boat	No. of fatalities	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			118.4			119.4			119				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	59.7					0.2	24		99.58		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
								2.40E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24	5.74E-08	23.88	5.74E-08	2.40E-09
								4.44E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								8.08E-07	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								7.03E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	59.7					0.2	24		99.58		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
									Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24		23.88		
								1.09E-09	Fatalities from head on collision only Speed assumed to be >=8 knots	b										0.2	24	2.61E-08	23.88	2.61E-08	1.09E-09
								2.02E-07	Fatalities from nudging fenders only Speed assumed to be >=8 knots	c															
								4.04E-07	Fatalities from glancing fenders only Speed assumed to be >=8 knots	d															
								3.20E-08	Severe glancing impact onto structure Speed assumed to be 4 knots	e															
								7.38E-04	Boat passes under bridge	f															
								2.40E-09																	
							Check sum	7.40E-04															Total PLL	8.35E-08	
								cool																	



Outcomes

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

Summary Results of Event Trees for Design Options 1 & 2

Design Option 1

V1 DO1 UP		V1 DO1 D		V2 DO1 UP		V2 DO1 D		V3 DO1 UP		V3 DO1 D	
No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency
202		282		111		163		117		174	
106		106		42		42		45		45	
106		106		42		42		45		45	
106	8.12E-08	106	1.55E-08	'42	9.21E-08	42	1.73E-08	45	9.21E-08	45	1.73E-08
202	1.48E-09	282	3.01E-09	111	1.67E-09	163	3.41E-09	117	1.67E-09	174	3.41E-09
106	3.45E-09	106	7.01E-09	42	3.91E-09	42	7.95E-09	45	3.91E-09	45	7.93E-09
106	4.92E-09	106		42	5.58E-09	42		45	5.58E-09	45	
106		106		42		42		45		45	
No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq
Total PLL for even	9.95E-06		3.93E-06		4.60E-06		2.18E-06		4.93E-06		2.32E-06

V4 DO1 UP		V4 DO1 D		V5 DO1 UP		V5 DO1 D		V6 DO1 UP		V6 DO1 D	
No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency
132		182		80		115		70		100	
66		66		28		28		24		24	
66		66		28		28		24		24	
66	4.60E-08	66	8.77E-09	28	4.60E-08	28	8.77E-09	24	2.66E-08	24	5.06E-09
132	8.37E-10	182	1.70E-09	80		115		70		100	
66	1.95E-09	66	3.97E-09	28		28		24		24	
66	2.79E-09	66		28		28		24		24	
66		66		28	5.58E-09	28	5.68E-09	24	3.22E-09	24	3.28E-09
No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq
	3.54E-06		1.41E-06		1.47E-06		4.10E-07		7.11E-07		1 99E-07

3.56E-05
Sum Total PLL

Design Option 1

FN Data

N	F	Cumulative Frequency
282	3.01E-09	3.01E-09
202	3.18E-09	6.19E-09
174	3.41E-09	9.59E-09
163	3.41E-09	1.30E-08
132	8.37E-10	1.38E-08
117	1.67E-09	1.55E-08
111	1.67E-09	1.72E-08
106	1.12E-07	1.29E-07
66	6.35E-08	1.93E-07
45	1.27E-07	3.20E-07
42	1.27E-07	4.47E-07
28	6.61E-08	5.13E-07
24	3.81E-08	5.51E-07
	5.51E-07	

5.51E-07

Design Option 2

V1 DO2 UP		V1 DO2 D		V2 DO2 UP		V2 DO2 D		V3 DO2 UP		V3 DO2 D	
No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency
202		282		111		163		117		174	
106		106		42		42		45		45	
106		106		42		42		45		45	
106	7.35E-09	106	7.35E-09	42	8.33E-09	42	8.33E-09	45	8.33E-09	45	8.33E-09
202	5.02E-10	282	1.00E-09	111	5.69E-10	163	1.14E-09	117	5.69E-10	174	1.14E-09
106	1.17E-09	106	2.34E-09	42	1.33E-09	42	2.65E-09	45	1.33E-09	45	2.65E-09
106	1.67E-09	106		42	1.90E-09	42		45	1.90E-09	45	
106		106		42		42		45		45	
No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq
Total PLL for even	1.24E-06		1.34E-06		6.00E-07		8.30E-07		6.41E-07		8.87E-07

V4 DO2 UP		V4 DO2 D		V5 DO2 UP		V5 DO2 D		V6 DO2 UP		V6 DO2 D	
No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency
132		182		80		115		70		100	
66		66		28		28		24		24	
66		66		28		28		24		24	
66	4.17E-09	66	4.17E-09	28	4.17E-09	28	4.17E-09	24	2.40E-09	24	2 40E-09
132	2.84E-10	182	5.69E-10	80		115		70		100	
66	6.64E-10	66	1.33E-09	28		28		24		24	
66	9.48E-10	66		28		28		24		24	
66		66		28	1.90E-09	28	1.90E-09	24	1.09E-09	24	1 09E-09
No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq
	4.44E-07		5.54E-07		1.72E-07		1.72E-07		8.35E-08		8.35E-08

7 25E-06

Design Option 2

FN Data

N	F	Cumulative Frequency
282	1.00E-09	1.00E-09
202	1.07E-09	2.07E-09
174	1.14E-09	3.21E-09
163	1.14E-09	4.35E-09
132	2.84E-10	4.64E-09
117	5.69E-10	5.20E-09
111	5.69E-10	5.77E-09
106	1.99E-08	2.57E-08
66	1.13E-08	3.69E-08
45	2.25E-08	5.95E-08
42	2.25E-08	8.20E-08
28	1.21E-08	9.41E-08
24	6.99E-09	1 01E-07
	1.01E-07	
	1.01E-07	check

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

Design Option 1

Frequency of	1 DO1 U	V1 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	
Fatalities from jet,pool fire & collision													
Fatalities from head on collision only													
Fatalities from head on collision only													
Fatalities from head on collision only	8.12E-08	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
Fatalities from nudging fenders only	1.50E-05	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
Fatalities from glancing fenders only	3.00E-05	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
Severe glancing impact onto structure	2.38E-06	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
Fatalities from jet,pool fire & collision	1.48E-09	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
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
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	1.85E-06	2.06E-06	2.10E-06	2.06E-06	2.10E-06	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 only	3.64E-06	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	2.93E-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 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	7.40E-04	2.1.E-02

Design option 1
Frequency of Collision

Nav span collision	
Head on	4.6.E-07
Glance	2.7.E-04
Non nav span collision	
Head on	9.4.E-08
Glance	5.5.E-05
Pass through	2.1.E-02
	2.1.E-02
check	1

Design Option 2

Frequency of	1 DO2 U	V1 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	
Fatalities from jet,pool fire & collision													
Fatalities from head on collision only													
Fatalities from head on collision only													
Fatalities from head on collision only	7.35E-09	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
Fatalities from nudging fenders only	1.36E-06	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
Fatalities from glancing fenders only	2.72E-06	2.72E-06	3.08E-06	3.08E-06	3.08E-06	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
Severe glancing impact onto structure	2.15E-07	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
Fatalities from jet,pool fire & collision	5.02E-10	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
Fatalities from head on collision only	1.17E-09	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
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	6.19E-07	6.19E-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	1.24E-06	1.24E-06	1.40E-06	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	9.79E-08	9.79E-08	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	2.26E-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	2.26E-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 option 2
Frequency of Collision

Nav span collision	
Head on	6.9.E-08
Glance	4.1.E-05
Non nav span collision	
Head on	3.2.E-08
Glance	1.8.E-05
Pass through	2.1.E-02
	2.1.E-02
check	1

Appendix 3

Event Trees for Sensitivity

Design Options Sensitivity Input Data

DO1	Strengthening Nav Spans elongating them by 5.5m
DO2	Widening of Nav spans

Diff between Sen and calc

V2 slightly smaller boat

		V1	370	tonnes		V2	270	tonnes		V3	190	tonnes		V4
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream
Tree Data	1	V1 DO1 UP	V1 DO1 D	V1 DO2 UP	V1 DO2 D	V2 DO1 UP	V2 DO1 D	V2 DO2 UP	V2 DO2 D	V3 DO1 UP	V3 DO1 D	V3 DO2 UP	V3 DO2 D	V4 DO1 UP
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
No. of people exposed on b	3	800	800	800	800	525	525	525	525	450	450	450	450	400
No. of people exposed on b	4	16	16	16	16	16	16	16	16	16	16	16	16	16
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
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
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	9	0.0018	0.0018	0.0018	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	0.33	0.33	0.33	0.33
Causes Structural failure N	#	1	1	1	1	1	1	1	1	1	1	1	1	1
Causes Structural failure N	#	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas/oil pipeline failure	#	0.5	1	0.5	1	0.5	1	0.5	1	0.5	1	0.5	1	0.5
Ignition	#	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Bridge fatality rate from po	#	1	1	1	1	1	1	1	1	1	1	1	1	1
Boat fatality rate from jet &	#	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5	0.25
Boat fatality rate glancing c	#	0	0	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

Design Options Sensitivity Input Data

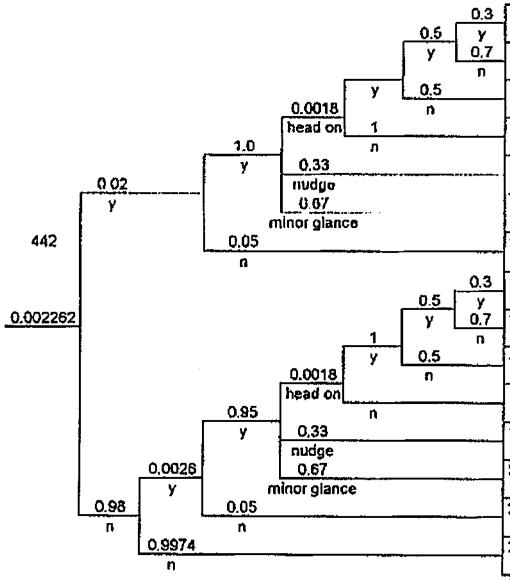
		155	tonnes		V5	115	tonnes		Boats smaller V6	45	tonnes	
		Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Tree Data	1	V4 DO1 D	V4 DO2 UP	V4 DO2 D	V5 DO1 UP	V5 DO1 D	V5 DO2 UP	V5 DO2 D	V6 DO1 UP	V6 DO1 D	V6 DO2 UP	V6 DO2 D
Frequency	2	1.28E-03	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	3	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	0.95	0.95
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	0.0018
Glances	#	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	#	1	1	1	0	0	0	0	0	0	0	0
Causes Structural failure	#	0	0	0	0	0	0	0	0	0	0	0
Gas/oil pipeline failure	#	1	0.5	1	0.5	1	0.5	1	0.5	1	0.5	1
Ignition	#	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Bridge fatality rate from p	#	1	1	1	1	1	1	1	1	1	1	1
Boat fatality rate from jet	#	0.5	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5	0.25	0.5
Boat fatality rate glancing	#	0	0	0	0	0	0	0	0	0	0	0
Boat fatality rate sinking/d	#	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33

Event tree for passage through Fremantle Bridge
Boat Name : Vessel 1
Code V1 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening
Upstream of bridge, travelling into the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat

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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/OilPipeline rupture	Ignition	Frequency	Outcome		Fatality Rate from pool and jet fire exposure	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure	No. of fatal ties	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			800			800			800				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	200					0.33	264		480		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
								8.12E-08	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264	2.14E-05	264	2.14E-05	8.12E-08
								1.50E-05	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								3.00E-05	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								2.38E-06	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								1.48E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	5.51E-08	0.25	200	6.89E-07				0.33	264	3.90E-07	480	1.13E-06	1.48E-09
								3.45E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264	9.10E-07	264	9.10E-07	3.45E-09
								4.92E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264	1.30E-06	264	1.30E-06	4.92E-09
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
								1.82E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								3.64E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								2.88E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								2.21E-03	Boat passes under bridge	f															



8.47E-08
Check sum 2.26E-03
cool

Total PLL 2.48E-05

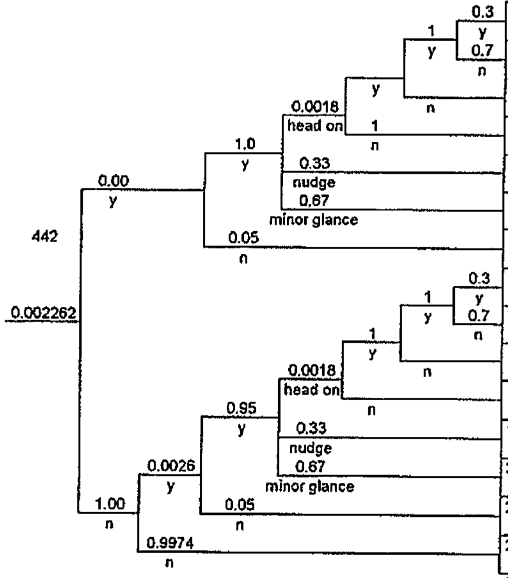
Outcomes

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 1</u>
Code V1 DO1 D
Design Option 1 Addition of dolphins and fender strengthening
Downstream of bridge, travelling from the harbour

People exposed on bridge — Immediate — People exposed on boat

Events — Consequences Bridge — Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality 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 Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No. of fatalities	Total PLL	Freq
												16			800			800			800				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	400					0.33	264		680		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
								1.55E-08	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264	4 09E-06	264	4.09E-06	1.55E-08
								2.86E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								5.72E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								4.52E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								3.01E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	1.12E-07	0.5	400	2 81E-06				0.33	264	7 93E-07	680	3.71E-06	3 01E-09
								7.01E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264	1.85E-06	264	1.85E-06	7.01E-09
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
								1.85E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								3.70E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								2.93E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								2.25E-03	Boat passes under bridge	f															
								2.25E-08																	

Outcomes

Check sum 2.26E-03
cool

Total PLL 9.65E-06

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 : Vessel 1
Code V1 DO2 UP
Design Option 2 **Widening of navigation spans**
Upstream of bridge, travelling into the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat

1 Frequency	2 Strikes Nav Span	3 Strikes Non Nav span	4 Strikes at speed greater than 4 knots	5 Strikes bridge	6 Causes Structural failure	7 Gas/Oil Pipeline rupture	8 Ignition	9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
												16			800			800			800				
						0.5	0.3 y		Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	200					0.33	264		480		
						y	0.7 n		Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
				0.0018	y	0.5 n			Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
			1.0	head on	1 n			7.35E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264	1.94E-06	264	1.94E-06	7.35E-09
	0.00		y	0.33 nudge				1.36E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
	y			0 67 minor glance				2 72E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
442			0.05 n					2.15E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
						0.5	0.3 y	5.02E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	1.87E-08	0.25	200	2.34E-07				0.33	264	1.33E-07	480	3.86E-07	5.02E-10
0.002262						y	0.7 n	1.17E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264	3 09E-07	264	3.09E-07	1.17E-09
				0.0018	1 y	0.5 n		1.67E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264	4.42E-07	264	4.42E-07	1.67E-09
			0.95	head on	n				Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
			y	0.33 nudge				6.19E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
		0.0009 y		0.67 minor glance				1.24E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
	1.00 n		0.05 n					9.79E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
		0.9991 n						2.26E-03	Boat passes under bridge	f															
								8.52E-09																	

Outcomes

Check sum 2.26E-03
cool

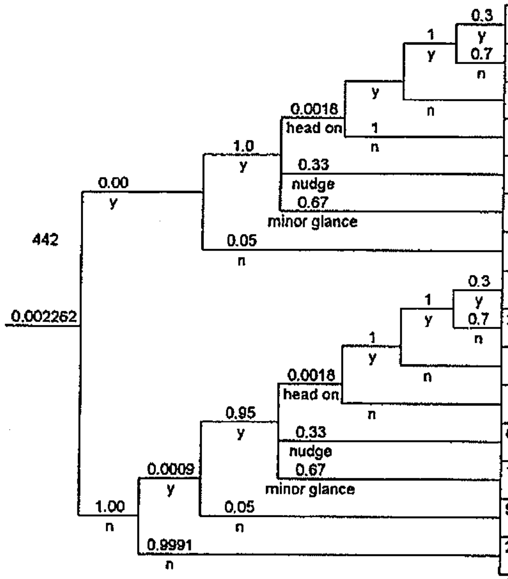
Total PLL 3.08E-06

- 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 1</u>
Code V1 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge (columns 12–14)
Consequences Boat (columns 15–23)



1 Frequency	2 Strikes Nav Span	3 Strikes Non Nav span	4 Strikes at speed greater than 4 knots	5 Strikes bridge	6 Causes Structural failure	7 Gas/Oil Pipeline rupture	8 Ignition	9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure	15 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
												16			800			800			800				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	400					0.33	264		680		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	264		264		
								7.35E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264	1 94E-06	264	1.94E-06	7 35E-09
								1.36E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								2.72E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								2.15E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								1.00E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	3.75E-08	0.5	400	9 37E-07				0.33	264	2 65E-07	680	1.24E-06	1.00E-09
								2.34E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264	6.18E-07	264	6.18E-07	2.34E-09
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	264		264		
								6.19E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								1.24E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								9.79E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								2.26E-03	Boat passes under bridge	f															

9.69E-09
Outcomes Check sum 2.26E-03
cool

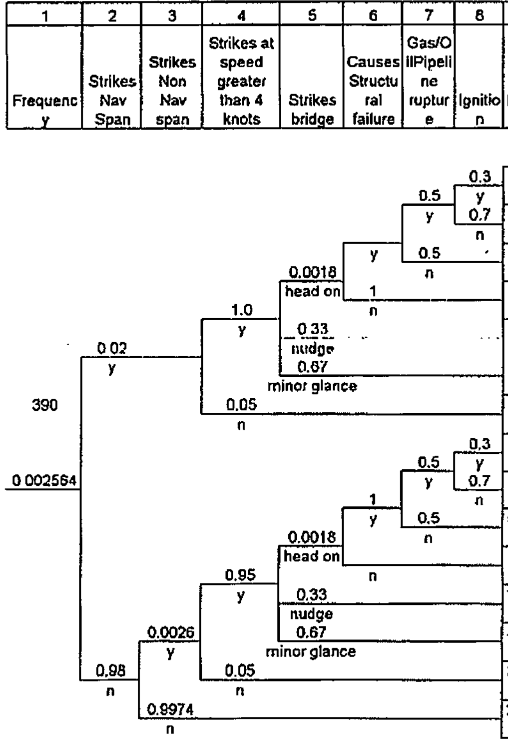
Total PLL 3.80E-06

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 : 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
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality 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 Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No. of fatalities	Total PLL	Freq
				16			525			525			525				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	131.25					0.33	173		320.5		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173 25		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173.25		
9.21E-08	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173	1.60E-05	173.25	1.60E-05	9.21E-08
1 70E-05	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
3.40E-05	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
2 69E-06	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
1.67E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	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-09
3.91E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173	6 77E-07	173.25	6.77E-07	3.91E-09
5.58E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173	9.67E-07	173.25	9.67E-07	5.58E-09
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173.25		
2.06E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
4.13E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
3.26E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
2.50E-03	Boat passes under bridge	f															
9.60E-08																	
Check sum 2.56E-03																	
cool																	

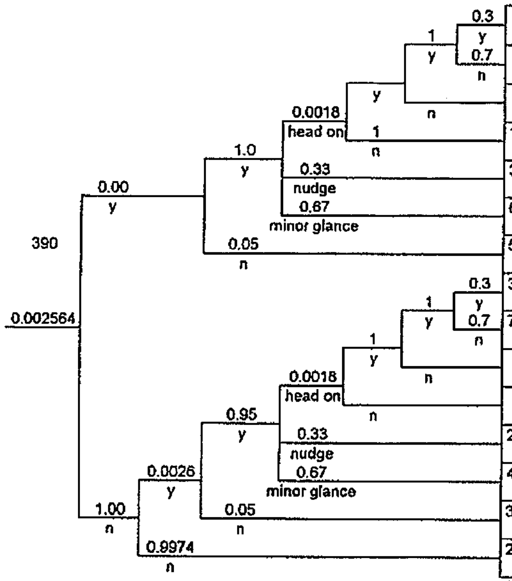
Total PLL 1.85E-05

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 : 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
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/OilPipeline rupture	Ignition	Frequency	Outcome		Fatality 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 Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No. of fatalities	Total PLL	Freq
												16			525			525			525				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	262.5					0.33	173		451.75		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173 25		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173.25		
								1.75E-08	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173	3 04E-06	173.25	3.04E-06	1.75E-08
								3.24E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								6.48E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								5.13E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								3.41E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	1.27E-07	0.5	262 5	2 09E-06				0.33	173	5.90E-07	451.75	2.80E-08	3.41E-09
								7.95E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173	1.38E-06	173.25	1.38E-08	7.95E-09
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173.25		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173.25		
								2.10E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								4.20E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								3.32E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								2.55E-03	Boat passes under bridge	f															
								2.55E-08																	

Outcomes

Check sum 2.56E-03
cool

Total PLL 7.22E-06

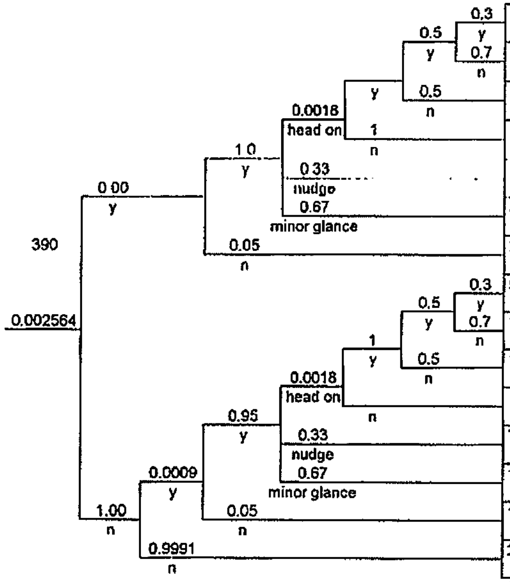
a	Natural gas / Oil pipeline
b	Head on collison > 8 knots
c	Nudging collision > 8 knots
d	Glancing collision > 8 knots
e	Severe glancing impact onto structure. LOP
f	Straight through

Event tree for passage through Fremantle Bridge
Boat Name : Vessel 2
Code V2 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

People exposed on bridge
Immediate
People exposed on boat

Events

1 Frequency	2 Strikes Nav Span	3 Strikes Non Nav span	4 Strikes at speed greater than 4 knots	5 Strikes bridge	6 Causes Structural failure	7 Gas/Oil Pipeline rupture	8 Ignition



Outcomes

Consequences Bridge / **Consequences Boat**

9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	18 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
				16			525			525			525				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	131.25					0.33	173		320,5		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173.25		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173.25		
8.33E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	173	1 44E-06	173 25	1.44E-06	8.33E-09
1 54E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
3.08E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
2.44E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
5.69E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	2.12E-08	0.25	131.25	1.74E-07				0.33	173	9.86E-08	320 5	2 94E-07	5.69E-10
1.33E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173	2.30E-07	173.25	2.30E-07	1.33E-09
1.90E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173	3.29E-07	173.25	3.29E-07	1.90E-09
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173.25		
7.01E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
1.40E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
1.11E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
2.56E-03	Boat passes under bridge	f															

9.66E-09
Check sum 2.56E-03
cool

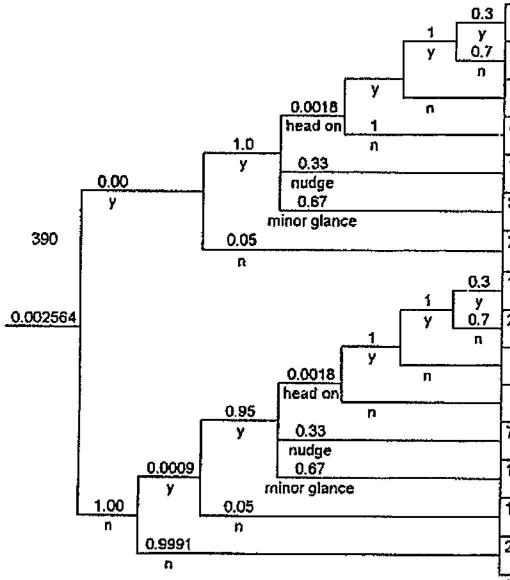
Total PLL 2.30E-06

- 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 : Vessel 2
Code V2 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/OilPipeline rupture	Ignition	Frequency	Outcome		Fatality 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 Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No. of fatalities	Total PLL	Freq
												16			525			525			525				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	262.5					0.33	173		451.75		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173.25		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173.25		
								8.33E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173	1 44E-06	173.25	1.44E-06	8.33E-09
								1.54E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								3.08E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								2.44E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								1.14E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	4.25E-08	0.5	262.5	6.97E-07				0.33	173	1 97E-07	451.75	9.37E-07	1.14E-09
								2.65E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173	4 60E-07	173.25	4.60E-07	2.65E-09
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173 25		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	173		173 25		
								7.01E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								1.40E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								1.11E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								2.56E-03	Boat passes under bridge	f															
								1.10E-08																	

Outcomes
Check sum 2.56E-03
cool

Total PLL 2.84E-06

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

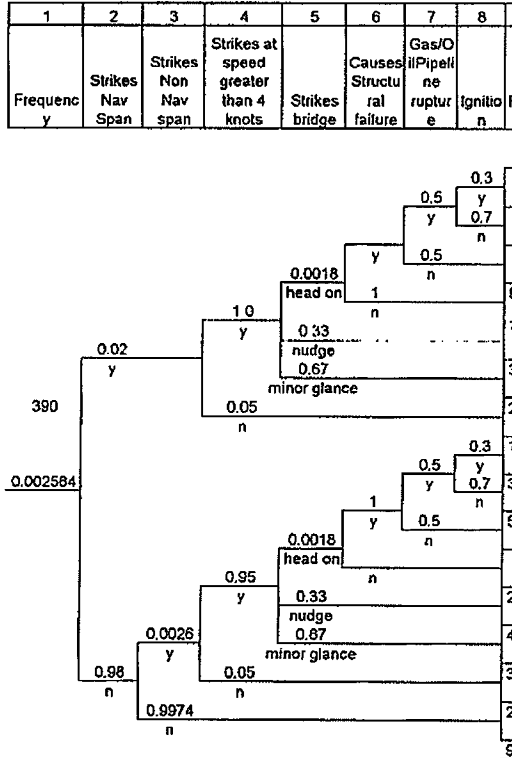
Event tree for passage through Fremantle Bridge
Boat Name : Vessel 3
Code V3 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening
Upstream of bridge, travelling into the harbour

People exposed on bridge

Immediate

People exposed on boat

Events



Consequences Bridge — Consequences Boat

9	10		11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome			Fatality 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 Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No of fatalities	Total PLL	Freq
					16			450			450			450				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a		1	16		0.25	112.5					0.33	149		277		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b											0.33	149		148.5		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b											0 33	149		148.5		
9.21E-08	Fatalities from head on collision o Speed assumed to be >=8 knots	b											0 33	149	1 37E-05	148.5	1.37E-05	9 21E-08
1 70E-05	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c																
3.40E-05	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d																
2.69E-06	Severe glancing impact onto struc Speed assumed to be 4 knots	e																
1.67E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a		1	16	6.25E-08	0.25	112 5	4.39E-07				0.33	149	2 49E-07	277	7.51E-07	1.67E-09
3.91E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b											0.33	149	5 80E-07	148.5	5.80E-07	3.91E-09
5.58E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b											0.33	149	8.29E-07	148.5	8.29E-07	5.58E-09
	Fatalities from head on collision o Speed assumed to be >=8 knots	b											0.33	149		148.5		
2.06E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c																
4.13E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d																
3.26E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e																
2.50E-03	Boat passes under bridge	f																
9.60E-08																		

Check sum 2.56E-03
cool

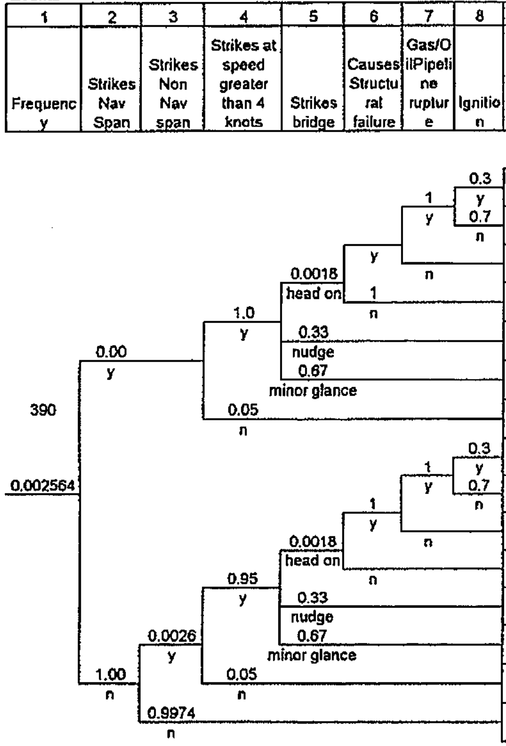
Total PLL 1.58E-05

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 : Vessel 3
Code V3 DO1 D
Design Option 1 Addition of dolphins and fender strengthening
Downstream of bridge, travelling from the harbour

People exposed on bridge
Immediate
People exposed on boat

Events



Consequences Bridge | Consequences Boat

9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No of fatalities	20 PLL	21 Total No of fatalities	22 Total PLL	23 Freq
				16			450			450			450				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	225					0.33	149		389.5		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
1.75E-08	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149	2 60E-06	148 5	2.60E-06	1.75E-08
3.24E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
6.48E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
5.13E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
3.41E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	1.27E-07	0.5	225	1.79E-06				0.33	149	5.06E-07	389.5	2 42E-06	3.41E-09
7.95E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149	1.18E-06	148.5	1.18E-06	7.95E-09
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
2.10E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
4.20E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
3.32E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
2.55E-03	Boat passes under bridge	f															

2.55E-08

Outcomes

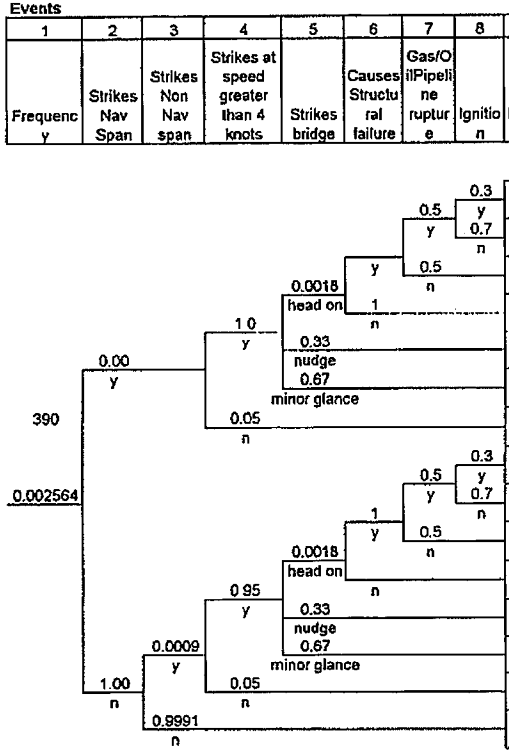
Check sum 2.56E-03
cool

Total PLL 6 21E-06

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 : Vessel 3
Code V3 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

Events



			Consequences Bridge			Consequences Boat									
			People exposed on bridge			Immediate			People exposed on boat						
9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality Rate from pool and jet fire exposure	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure	No. of fatal ties	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			450			450			450				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	112.5					0.33	149		277		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
8 33E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	149	1 24E-06	148 5	1 24E-06	8 33E-09
1 54E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
3.08E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
2.44E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
5.69E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	2.12E-08	0.25	112.5	1.49E-07				0.33	149	8 45E-08	277	2.55E-07	5 69E-10
1,33E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149	1.97E-07	148.5	1.97E-07	1.33E-09
1,90E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149	2,82E-07	148.5	2.82E-07	1.90E-09
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
7.01E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
1.40E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
1.11E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
2.56E-03	Boat passes under bridge	f															
9.66E-09															Total PLL	1.97E-06	

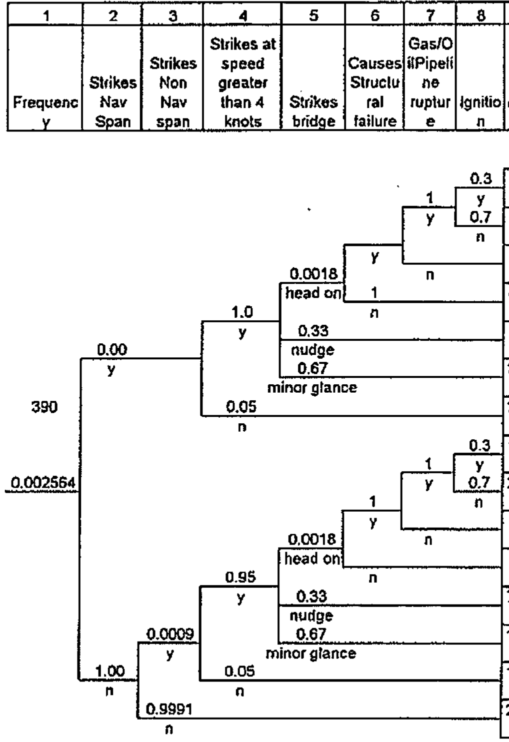
Check sum 2.56E-03
cool

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 : Vessel 3
Code V3 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

People exposed on boat
People exposed on bridge
Immediate

Events
Consequences Bridge
Consequences Boat



9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality 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 Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No. of fatalities	Total PLL	Freq
				16			450			450			450				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	225					0.33	149		389.5		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
8.33E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149	1.24E-06	148.5	1.24E-06	8.33E-09
1.54E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
3.08E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
2.44E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
1.14E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	4.26E-08	0.5	225	5.97E-07				0.33	149	1 69E-07	389.5	8.09E-07	1.14E-09
2.65E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149	3.94E-07	148.5	3.94E-07	2.65E-09
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	149		148.5		
7.01E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
1.40E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
1.11E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
2.56E-03	Boat passes under bridge	f															
1.10E-08																	

Outcomes

Check sum 2.56E-03
cool

Total PLL 2.44E-06

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

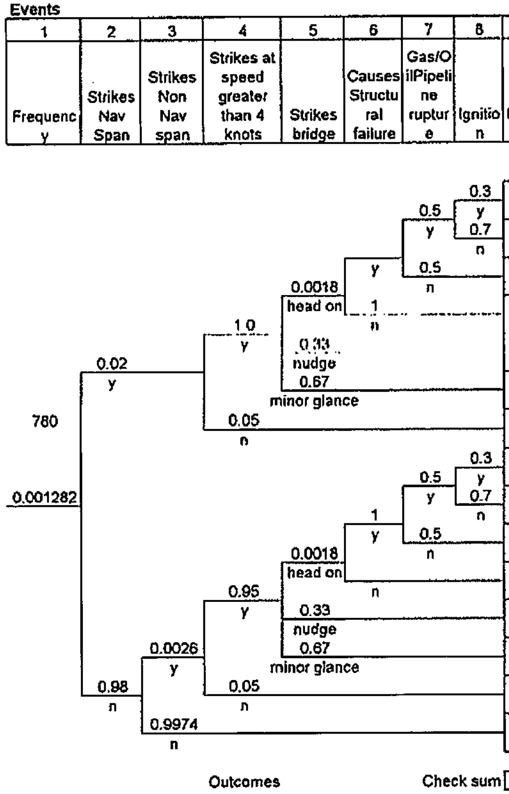
Event tree for passage through Fremantle Bridge
Boat Name : Vessel 4
Code V4 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening
Upstream of bridge, travelling into the harbour

People exposed on bridge

Immediate

People exposed on boat

Events



Consequences Bridge | Consequences Boat

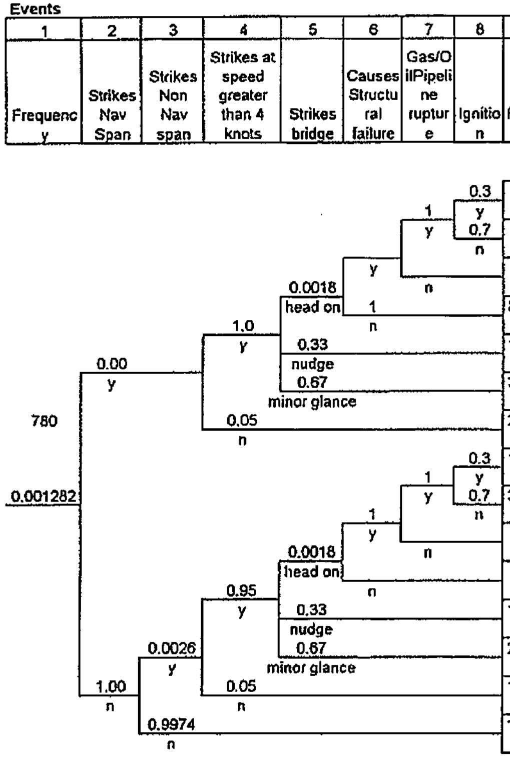
9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
				16			400			400			400				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	100					0.33	132		248		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
4 60E-08	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	132	6 08E-06	132	6 08E-06	4 60E-08
8 51[illegible]	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
1.70E-05	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
1.35E-06	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
8 37E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	3.12E-08	0.25	100	1.95E-07				0.33	132	1 10E-07	248	3.37E-07	8 37E-10
1.95E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132	2 58E-07	132	2 58E-07	1.95E-09
2.79E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132	3.68E-07	132	3.68E-07	2.79E-09
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	132		132		
1.03E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
2.06E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
1.63E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
1.25E-03	Boat passes under bridge	f															
4.80E-08																	
Check sum 1.28E-03															Total PLL	7.04E-06	
cool																	

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 : Vessel 4
Code V4 DO1 D
Design Option 1 Addition of dolphins and fender strengthening
Downstream of bridge, travelling from the harbour

People exposed on bridge
Immediate
People exposed on boat

Events



			Consequences Bridge			**Consequences Boat**											
9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality 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 Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No. of fatalities	Total PLL	Freq
				16			400			400			400				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	200					0.33	132		348		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
8.77E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132	1.16E-06	132	1.16E-06	8.77E-09
1.62E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
3.24E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
2.56E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
1.70E-09	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	6.36E-08	0.5	200	7 95E-07				0.33	132	2 25E-07	348	1.08E-06	1.70E-09
3.97E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132	5.25E-07	132	5.25E-07	3.97E-09
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
1.05E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
2.10E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
1.66E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
1.27E-03	Boat passes under bridge	f															
1.27E-08																	

Outcomes

Check sum 1.28E-03
cool

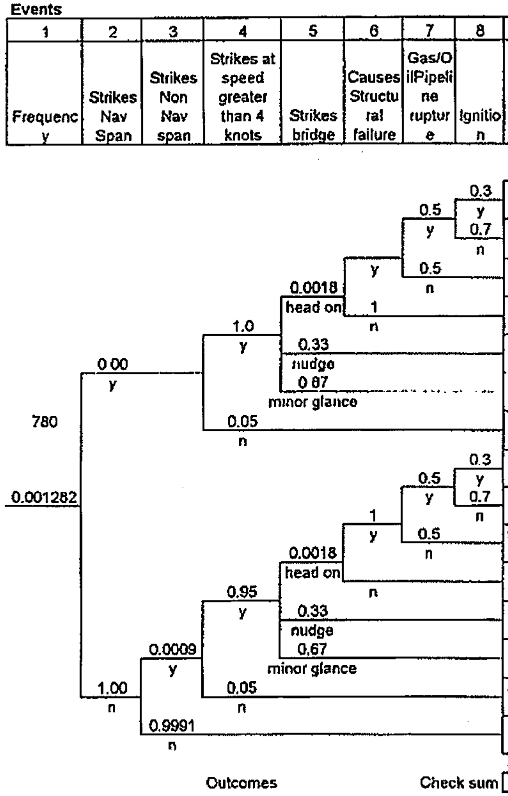
Total PLL 2.77E-08

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 : Vessel 4
Code V4 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
				16			400			400			400				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	100					0.33	132		248		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
4 17E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132	5 50E-07	132	5.50E-07	4.17E-09
7.70E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
1 54E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
1.22E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
2.84E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	1.06E-08	0.25	100	6.64E 08				0.33	132	3 75E-08	248	1 15E-07	2 84E-10
6.64E-10	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132	8 76E-08	132	8 76E-08	6.64E-10
9.48E-10	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132	1.25E-07	132	1.25E-07	9.48E-10
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
3.51E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
7.01E-07	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
5.55E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
1.28E-03	Boat passes under bridge	f															

4.83E-09
Check sum 1.28E-03
cool

Total PLL 8.77E-07

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 : Vessel 4
Code V4 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

People exposed on bridge

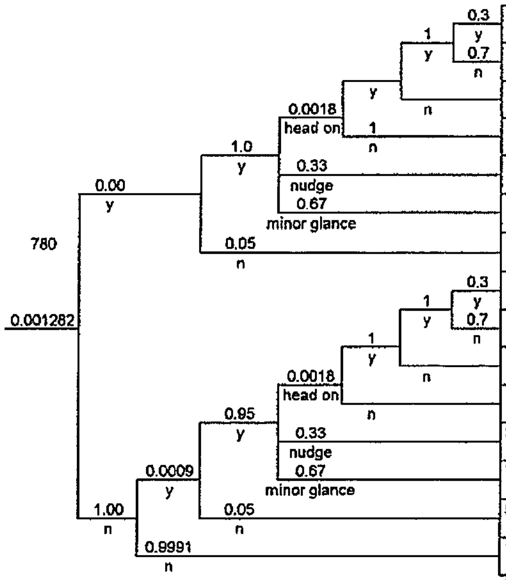
Immediate

People exposed on boat

Events

Consequences Bridge

Consequences Boat



1 Frequency	2 Strikes Nav Span	3 Strikes Non Nav span	4 Strikes at speed greater than 4 knots	5 Strikes bridge	6 Causes Structural failure	7 Gas/OilPipeline rupture	8 Ignition	9 Frequency	10 Outcome	11	12 Fatality Rate from pool and jet fire exposure	13 No. of fatalities	14 PLL	15 Fatality Rate from pool and jet fire exposure	16 No. of fatalities	17 PLL	18 Boat Collision Glancing Fatality Rate	19 No. of fatalities	20 PLL	18 Boat Collision Head On Fatality Rate	19 No. of fatalities	20 PLL	21 Total No. of fatalities	22 Total PLL	23 Freq
												16			400			400			400				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	200					0.33	132		348		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
								4.17E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132	5.50E-07	132	5 50E-07	4.17E-09
								7.70E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								1.54E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								1.22E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								5.69E-10	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16	2.12E-08	0.5	200	2.65E-07				0.33	132	7 51E-08	348	3.62E-07	5.69E-10
								1.33E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132	1.75E-07	132	1.75E-07	1.33E-09
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	132		132		
								3.51E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								7.01E-07	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								5.55E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								1.28E-03	Boat passes under bridge	f															

5.49E-09

Outcomes

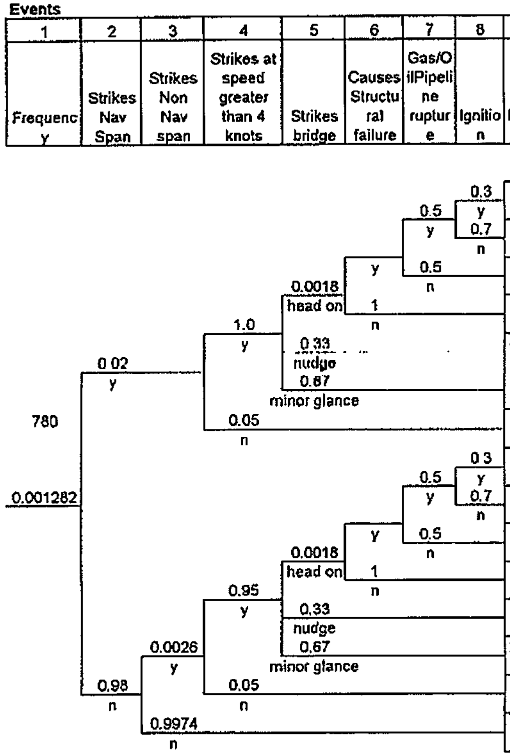
Check sum 1.28E-03
cool

Total PLL 1.09E-06

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 : Vessel 5
Code V5 DO1 UP
Design Option 1 Addition of dolphins and fender strengthening
Upstream of bridge, travelling into the harbour

Events



People exposed on bridge | Immediate | People exposed on boat

Consequences Bridge | Consequences Boat

9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
Frequency	Outcome		Fatality 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 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				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	71					0.33	94		180.72		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93 72		
4.60E-08	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	94	4.31E-06	93 72	4.31E-06	4.60E-08
8.51E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
1.70E-05	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
1.35E-06	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	71					0.33	94		180.72		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
5.58E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94	5 23E-07	93.72	5.23E-07	5.58E-09
1.03E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
2.06E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
1.63E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
1.25E-03	Boat passes under bridge	f															
4.60E-08																	

Outcomes

Check sum 1.28E-03
cool

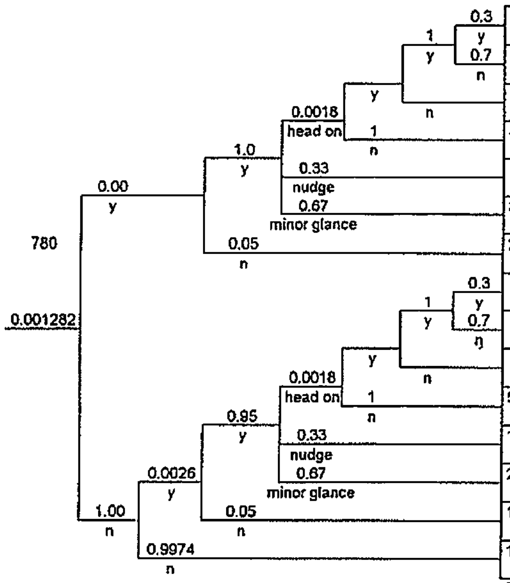
Total PLL 4.84E-06

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 : 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
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality 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 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				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	142					0.33	94		251.72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93 72		
								8.77E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94	8 22E-07	93 72	8.22E-07	8.77E-09
								1.62E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								3.24E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								2.56E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	142					0 33	94		251 72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93 72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
								5.68E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94	5 32E-07	93.72	5.32E-07	5.68E-09
								1.05E-06	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								2.10E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								1.66E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								1.27E-03	Boat passes under bridge	f															

8.77E-09
Outcomes
Check sum 1.28E-03
cool

Total PLL 1.35E-06

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 : Vessel 5
Code V5 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

People exposed on bridge

Immediate

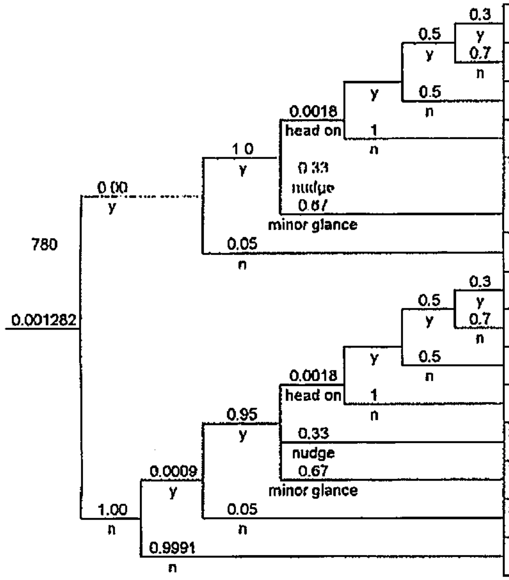
People exposed on boat

Events

Consequences Bridge

Consequences Boat

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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality 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 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				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	71					0.33	94		180.72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
								4.17E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94	3 90E-07	93.72	3 90E-07	4 17E-09
								7 70E 07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								1 54E-08	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								1.22E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	71					0.33	94		180.72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
								1.90E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94	1.78E-07	93.72	1.78E-07	1.90E-09
								3.51E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								7.01E-07	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								5.55E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								1.28E-03	Boat passes under bridge	f															



4.17E-09

Outcomes

Check sum 1.28E-03

cool

Total PLL 5.68E-07

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 : Vessel 5
Code V5 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

People exposed on bridge

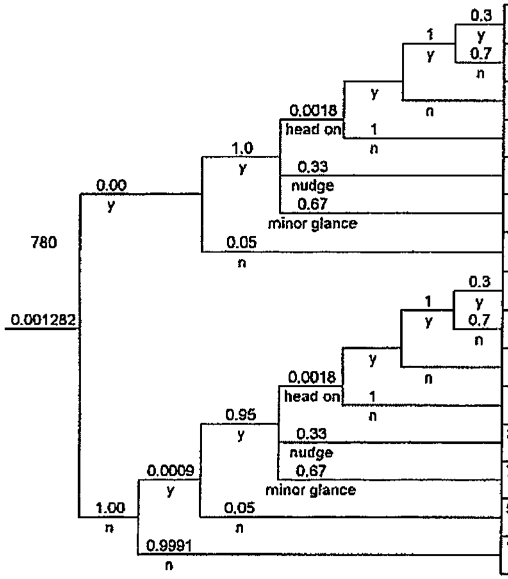
Immediate

People exposed on boat

Events

Consequences Bridge

Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality 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 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				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	142					0 33	94		251.72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	94		93.72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	94		93.72		
								4.17E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94	3.90E-07	93 72	3.90E-07	4.17E-09
								7.70E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								1.54E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								1.22E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	142					0.33	94		251 72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94		93.72		
								1.90E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	94	1 78E-07	93 72	1.78E-07	1.90E-09
								3.51E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								7.01E-07	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								5.55E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								1.28E-03	Boat passes under bridge	f															

4.17E-09

Outcomes

Check sum 1.28E-03
cool

Total PLL 5.68E-07

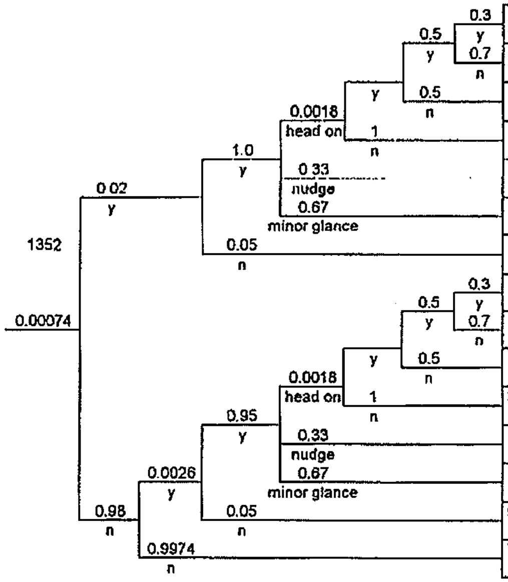
a	Natural gas / Oil pipeline
b	Head on collison > 8 knots
c	Nudging collision > 8 knots
d	Glancing collision > 8 knots
e	Severe glancing impact onto structure. LOP
f	Straight through

Event tree for passage through Fremantle Bridge
Boat Name : 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 boat
People exposed on bridge
Immediate

Events
Consequences Bridge
Consequences Boat

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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality Rate from pool and jet fire exposure	No. of fatalities	PLL	Fatality Rate from pool and jet fire exposure	No. of fatal ties	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



9	10	11	12	13	14	15	16	17	18	19	20	18	19	20	21	22	23
				16			199			199			199				
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	49.75					0 33	66		131.42		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65 67		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
2 66E-08	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66	1 74E-06	65.67	1,74E-06	2.66E-08
4 01E 08	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
9 82E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
7.77E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
	Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	49.75					0.33	66		131.42		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
3.22E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	66	2 11E-07	65 67	2 11E-07	3.22E-09
5.95E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
1.19E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
9.41E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
7.22E-04	Boat passes under bridge	f															

2.66E-08
Check sum 7.40E-04
cool

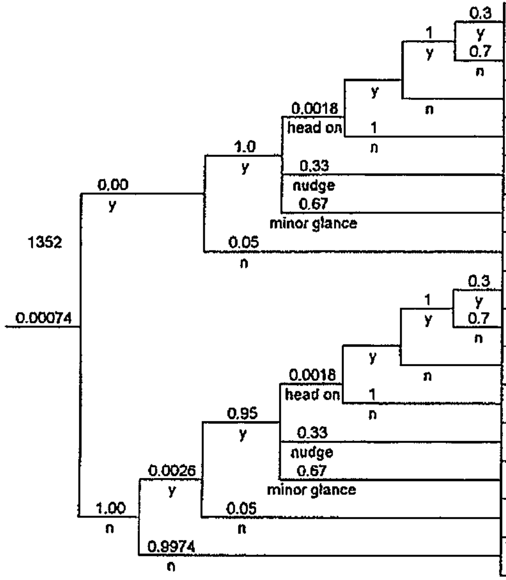
Total PLL 1.96E-06

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 : 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 boat
People exposed on bridge
Immediate

Events
Consequences Bridge
Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/Oil Pipeline rupture	Ignition	Frequency	Outcome		Fatality 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 Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No of fatalities	Total PLL	Freq
												16			199			199			199				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	99 5					0.33	66		181.17		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
								5.06E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66	3 32E-07	65.67	3.32E-07	5.06E-09
								9.35E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								1.87E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								1.48E-07	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	99 5					0.33	66		181 17		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65 67		
								3.28E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	66	2.15E-07	65 67	2 15E-07	3.28E-09
								6.05E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								1.21E-06	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								9.58E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								7.35E-04	Boat passes under bridge	f															

5.06E-09

Outcomes

Check sum 7.40E-04

cool

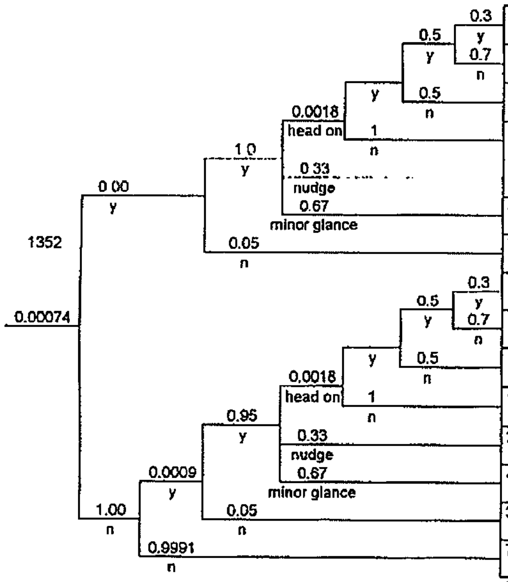
Total PLL 5.47E-07

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 : Vessel 6
Code V6 DO2 UP
Design Option 2 Widening of navigation spans
Upstream of bridge, travelling into the harbour

People exposed on bridge
Immediate
People exposed on boat

Events
Consequences Bridge
Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/OilPipeline rupture	Ignition	Frequency	Outcome		Fatality 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 Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No of fatalities	PLL	Total No. of fatalities	Total PLL	Freq
												16			199			199			199				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	49.75					0.33	66		131.42		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65 67		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65 67		
								2.40E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0 33	66	1 58E-07	65 67	1 58E-07	2 40E-09
								4 44E 07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								8.88E-07	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								7.03E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.25	49.75					0 33	66		131 42		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.87		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
								1.09E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66	7 18E-08	65 67	7 18E-08	1.09E-09
								2.02E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								4.04E-07	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								3.20E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								7.38E-04	Boat passes under bridge	f															
								2.40E-09																	
							Check sum	7.40E-04																	
								cool																	

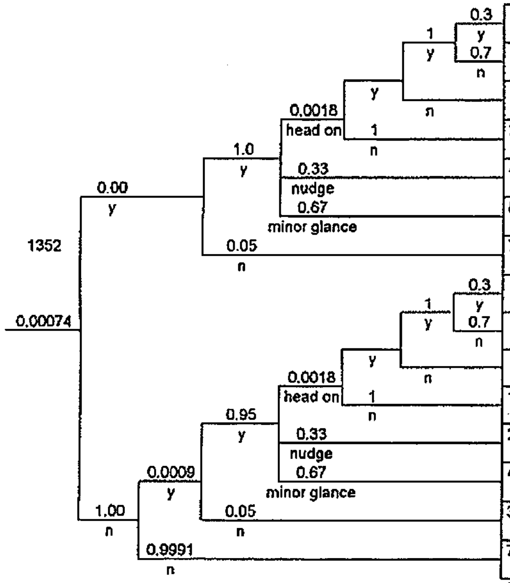
Total PLL 2.30E-07

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 : Vessel 6
Code V6 DO2 D
Design Option 2 Widening of navigation spans
Downstream of bridge, travelling from the harbour

People exposed on boat
People exposed on bridge
Immediate

Events
Consequences Bridge
Consequences Boat



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
Frequency	Strikes Nav Span	Strikes Non Nav span	Strikes at speed greater than 4 knots	Strikes bridge	Causes Structural failure	Gas/OilPipeline rupture	Ignition	Frequency	Outcome		Fatality 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 Rate	No. of fatalities	PLL	Boat Collision Head On Fatality Rate	No. of fatalities	PLL	Total No. of fatalities	Total PLL	Freq
												16			199			199			199				
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	99.5					0.33	66		181.17		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
								2.40E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66	1.58E-07	65 67	1.58E-07	2.40E-09
								4.44E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								8.88E-07	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								7.03E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
									Pipeline ruptures (NG or WO) Fatalities from jet,pool fire & collision	a	1	16		0.5	99.5					0 33	66		181.17		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
									Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66		65.67		
								1.09E-09	Fatalities from head on collision o Speed assumed to be >=8 knots	b										0.33	66	7 18E-08	65 67	7.18E-08	1 09E-09
								2.02E-07	Fatalities from nudging fenders on Speed assumed to be >=8 knots	c															
								4.04E-07	Fatalities from glancing fenders o Speed assumed to be >=8 knots	d															
								3.20E-08	Severe glancing impact onto struc Speed assumed to be 4 knots	e															
								7.38E-04	Boat passes under bridge	f															

2.40E-09
Check sum 7.40E-04
cool

Total PLL 2 30E-07

Outcomes

- 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

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

Design Option 1

V1 DO1 UP		V1 DO1 D		V2 DO1 UP		V2 DO1 D		V3 DO1 UP		V3 DO1 D		V4 DO1 UP		V4 DO1 D		V5 DO1 UP		V5 DO1 D		V6 DO1 UP		V6 DO1 D	
No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency
480		680		321		452		277		390		248		348		181		252		131		181	
264		264		173		173		149		149		132		132		94		94		66		66	
264		264		173		173		149		149		132		132		94		94		66		66	
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
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	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	
264	4.92E-09	264		173	5.58E-09	173		149	5.58E-09	149		132	2.79E-09	132		94		94		66		66	
264		264		173		173		149		149		132		132		94	5.58E-09	94	5.68E-09	66	3.22E-09	66	3.28E-09

	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	
Total PLL for e	2.48E-05		9.65E-06		1.85E-05		7.22E-06		1.58E-05		6.21E-06		7.04E-06		2.77E-06		4.84E-06		1.35E-06		1.96E-06		5 47E-07	1.01E-04

Sum Total PLL

Design Option 1

FN Data

N	F	Cumulative Frequency
680	3.01E-09	3.01E-09
480	3.18E-09	6.19E-09
390	3.41E-09	9.59E-09
452	3.41E-09	1.30E-08
248	8.37E-10	1.38E-08
277	1.67E-09	1.55E-08
321	1.67E-09	1.72E-08
264	1.12E-07	1.29E-07
132	6.35E-08	1.93E-07
149	1.27E-07	3.20E-07
173	1.27E-07	4.47E-07
94	6.61E-08	5.13E-07
66	3.81E-08	5.51E-07
	5.51E-07	
	5.51E-07	

Design Option 2

V1 DO2 UP		V1 DO2 D		V2 DO2 UP		V2 DO2 D		V3 DO2 UP		V3 DO2 D		V4 DO2 UP		V4 DO2 D		V5 DO2 UP		V5 DO2 D		V6 DO2 UP		V6 DO2 D	
No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency	No. of Fatalities	Frequency
480		680		321		452		277		390		248		348		181		252		131		181	
264		264		173		173		149		149		132		132		94		94		66		66	
264		264		173		173		149		149		132		132		94		94		66		66	
264	7.35E-09	264	7.35E-09	173	8.33E-09	173	8.33E-09	149	8.33E-09	149	8.33E-09	132	4.17E-09	132	4.17E-09	94	4.17E-09	94	4.17E-09	66	2.40E-09	66	2.40E-09
480	5.02E-10	680	1.00E-09	321	5.69E-10	452	1.14E-09	277	5.69E-10	390	1.14E-09	248	2.84E-10	348	5.69E-10	181		252		131		181	
264	1.17E-09	264	2.34E-09	173	1.33E-09	173	2.65E-09	149	1.33E-09	149	2.65E-09	132	6.64E-10	132	1.33E-09	94		94		66		66	
264	1.67E-09	264		173	1.90E-09	173		149	1.90E-09	149		132	9.48E-10	132		94		94		66		66	
264		264		173		173		149		149		132		132		94	1.90E-09	94	1.90E-09	66	1.09E-09	66	1.09E-09

	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	No. of fat	Freq	
Total PLL for e	3.08E-06		3.80E-06		2.30E-06		2.84E-06		1.97E-06		2.44E-06		8.77E-07		1.09E-06		5.58E-07		5.68E-07		2.30E-07		2.30E-07	2 00E-05

Design Option 2

FN Data

N	F	Cumulative Frequency
680	1.00E-09	1.00E-09
480	1.07E-09	2.07E-09
390	1.14E-09	3.21E-09
452	1.14E-09	4.35E-09
248	2.84E-10	4.64E-09
277	5.69E-10	5.20E-09
321	5.69E-10	5.77E-09
264	1.99E-08	2.57E-08
132	1.13E-08	3.69E-08
149	2.25E-08	5.95E-08
173	2.25E-08	8.20E-08
94	1.21E-08	9.41E-08
66	6.99E-09	1.01E-07
	1.01E-07	
	1.01E-07	check

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

Design Option 1

Frequency of	1 DO1 U	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	
Fatalities from jet,pool fire & co													
Fatalities from head on collision													
Fatalities from head on collision													
Fatalities from head on collision	8.12E-08	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
Fatalities from nudging fenders	1.50E-05	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
Fatalities from glancing fenders	3.00E-05	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
Severe glancing impact onto st	2.38E-06	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
Fatalities from jet,pool fire & co	1.48E-09	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
Fatalities from head on collision	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
Fatalities from head on collision	4.92E-09		5.58E-09		5.58E-09		2.79E-09						1.9.E-08
Fatalities from head on collision									5.58E-09	5.68E-09	3.22E-09	3.28E-09	1.8.E-08
Fatalities from nudging fenders	1.82E-06	1.85E-06	2.06E-06	2.10E-06	2.06E-06	2.10E-06	1.03E-06	1.05E-06	1.03E-06	1.05E-06	5.95E-07	6.05E-07	1.7.E-05
Fatalities from glancing fenders	3.64E-06	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 st	2.88E-07	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 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	7.40E-04	2.1.E-02

Design option 1

Frequency of Collisio

Nav span collision	
Head on	4.6.E-07
Glance	2.7.E-04
n nav span collision	
Head on	9.4.E-08
Glance	5.5.E-05
Pass through	2.1.E-02
	2.1.E-02
check	1

Design Option 2

Frequency of	1 DO2 U	1 DO2	2 DO2 U	2 DO2	3 DO2 U	3 DO2	4 DO2 U	4 DO2	5 DO2 U	5 DO2	6 DO2 U	6 DO2 D	
Fatalities from jet,pool fire & co													
Fatalities from head on collision													
Fatalities from head on collision													
Fatalities from head on collision	7.35E-09	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
Fatalities from nudging fenders	1.36E-06	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
Fatalities from glancing fenders	2.72E-06	2.72E-06	3.08E-06	3.08E-06	3.08E-06	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
Severe glancing impact onto st	2.15E-07	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
Fatalities from jet,pool fire & co	5.02E-10	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
Fatalities from head on collision	1.17E-09	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
Fatalities from head on collision	1.67E-09		1.90E-09		1.90E-09		9.48E-10						6.4.E-09
Fatalities from head on collision									1.90E-09	1.90E-09	1.09E-09	1.09E-09	6.0.E-09
Fatalities from nudging fenders	6.19E-07	6.19E-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	1.24E-06	1.24E-06	1.40E-06	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 st	9.79E-08	9.79E-08	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	2.26E-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	2.26E-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 option 2

Frequency of Collisio

Nav span collision	
Head on	6.9.E-08
Glance	4.1.E-05
n nav span collision	
Head on	3.2.E-08
Glance	1.8.E-05
Pass through	2.1.E-02
	2.1.E-02
check	1

Appendix 4

Frequency Questionnaire Data

Draught

Boat Name	No. of timetabled journeys (per week)	No. of charters on average (per week)	Operating on the Swan river (No. of Yrs)	Max Boat Capacity (people)	% full (approx)	Gross tonnage	Boat Width	Average speed through bridge	Any instances of boat glancing Fremantle bridge (please quantify)	Comments Your view on the Fremantle Bridge, suggestions, problems encountered, eg river traffic, tide, bridge alignment, etc
Captain Cook	14	2	1972	310		155	6.8m	8 KNTS	RARELY.	IT WOULD BE GREAT TO REMOVE THE CENTRE ARCH AND THEREFORE INCREASE
James Stirling	14	2	1995	400		~~115~~ 135	8.1m	8 KNTS	SLIGHT GLANCES ON BELTING (CENTRE ARCH)	THE WIDTH OF BOTH NTH & 5TH ARCHES. AND IN THE PROCESS INCREASE THE HEIGHT OF THE NTH ARCH WHICH IS
Swan Explorer	14	2	1956	180		75	7.1m	8 KNTS	NEVER	ONLY USABLE ON LOW TIDES. IF YOU NEED ANY FURTHER INFO PLEASE CALL.
Any other boats owned that may pass under the Fremantle Bridge										
										Regards MARK OSWALD (015 081 313)

FAX: 9325 3344.
TO: STEVE COOPER
QEST CONSULTING GROUP.
FROM: TONY DILATTE
OCEANIC CRUISES.

Boat Name	No. of timetabled journeys (per week)	No. of charters on average (per week)	Operating on the Swan river. (No. of Yrs)	Max Boat Capacity (people)	% full (approx)	Gross tonnage	Average speed through bridge	Any instances of boat glancing Fremantle bridge (please quantify)	Comments Your view on the Fremantle Bridge, suggestions, problems encountered, eg river traffic, tide, bridge alignment, etc	Draught
Sea Cat	28	NIL	8 months	284	50%	63.	10 KNTS		THE RAILWAY BRIDGE & THE OLD TRAFFIC BRIDGE SHOULD BE IN LINE WITH EACH OTHER, REASON BEING THAT THERE IS A STRONG CURRENT AT TIMES, WHICH COULD CAUSE AN ACCIDENT. THE HEIGHT OF THE BRIDGE SHOULD BE INCREASED BY 1.5M AS WELL AS 1.5M WIDER IN BETWEEN THE PYLONS	1.8
Any other boats that may pass through the Fremantle Bridge										
SUPERCAT II	24	4	3 years	199.	60%	44	10 KTS			1.6
CLASSIQUE	32	6	3 years.	167.	30%	32	8 KNOTS			0.9
RIVERCAT	32.	4	New. JUST COMMENCING	114	40%	27.	10 KNOTS			0.9

BOAT TORQUE

passes

(Survey's)

Draughts

Andrew Rossi

Boat Name	No. of timetabled journeys (per week)	No. of charters on average (per week)	Operating on the Swan river (No. of Yrs)	Max Boat Capacity (people)	% full (approx)	Gross tonnage	Boat Width	Average speed through bridge	Any instances of boat glancing Fremantle bridge (please quantify)	Comments Your view on the Fremantle Bridge, suggestions, problems encountered, eg river traffic, tide, bridge alignment, etc
Superflyte	14	2	6	525	40%			11knots	4/5 times 1/yr nudge	Major problem alignment forced to do dogleg
Sea Flyte	operates out of Hillarys Fremantle									northern span, sets onto the concrete span of railway bridge forced across, 90%
Star Flite	2	0	10	503	40%		1/2m	11knots	rarely manoeuverable	traffic big problem, line up 400m back, 10 knots keep steerage
Rottnest Explorer	14	2	20	803	40%	500	9·6	9	1/2 nudges 4/5 glances	▲ span tide height & traffic density, (boat on end of jetty) harbour side
Any other boat you may own										
70m, stop on loss of steerage	1 in 10yrs 2or3								→	miss concrete, pile in and a bit leads hanging down centre of spans, 50cm long, hanging each side
										of bridge, 47m (55cm safety margin) ▷ tide markings on bridge,

...months

...steel

...ed 60m,

=)

✱ put on Stirling traffic bridge, →
light fittings, bridge to