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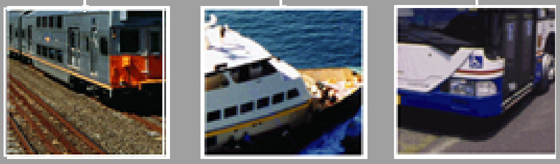

FERRY SAFETY INVESTIGATION REPORT

COLLISION OF THE MANLY FERRY *NARRABEEN* NUMBER 5 WHARF, CIRCULAR QUAY

26 MAY 2005

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OTSI File Ref: 04066

24 March 2006

The Office of Transport Safety Investigations
Level 21, 201 Elizabeth Street
Sydney NSW 2000

The Office of Transport Safety Investigations (OTSI) is an independent NSW agency whose purpose is to improve transport safety through the investigation of accidents and incidents in the rail, bus and ferry industries.

Established on 1 January 2004 by the *Transport Administration Act 1988*, the Office is responsible for determining the causes and contributing factors of accidents and to make recommendations for the implementation of remedial safety action to prevent recurrence.

OTSI investigations are conducted under powers conferred by the *Rail Safety Act 2002* and the *Passenger Transport Act 1990*. OTSI investigators normally seek to obtain information cooperatively when conducting an accident investigation. However, where it is necessary to do so, OTSI investigators may exercise statutory powers to interview persons, enter premises and examine and retain physical and documentary evidence. Where OTSI investigators exercise their powers of compulsion, information so obtained cannot be used by other agencies in any subsequent civil or criminal action against those persons providing information.

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Information about OTSI is available on its website or from its offices at:

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The Office of Transport Safety Investigations also provides a Confidential Safety Information Reporting facility for rail, bus and ferry industry employees. The CSIRS reporting telephone number is 1800 180 828.

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GLOSSARY OF TERMS AND ABBREVIATIONS

Bow	Front area of vessel
BHP	Brake Horse Power. An engine power output rating, as distinct from Shaft Horse Power SHP
CCTV	Closed Circuit Television
CPP	A Controllable Pitch Propeller has the thrust resulting from its constant rotation varied ahead or astern by pitch adjustment from a remote location, such as a vessel's bridge control console
CRM	Crew Resource Management. Training designed to ensure the use of all available resources to achieve safe and efficient operations by enhancing communication, teamwork and the capacity to respond to emergencies.
Ebb	Periodic seawater level falling due to decreasing tidal forces
EPA	Environmental Protection Agency
Evolutions	Ferry crew training drills and procedures undertaken by SFC as programs forming part of its safety management system (SMS)
FAID	Fatigue Audit InterDyne™ is the name given to a range of fatigue risk management software, developed by InterDynamics Pty Ltd
Ferry	A vessel which carries more than 8 adult persons, as defined by the *Passenger Transport Act 1990* (NSW)
GPH	A General Purpose Hand, or Deckhand, is a duly qualified crewmember not engaged in navigational or engineering duties
ICAM	Incident Cause Analysis Method
ISM Code	International Safety Management Code .The purpose of this Code is to provide an international standard for the safe management and operation of ships and for prevention of pollution at sea. Promulgated by the International Maritime Organisation (IMO).
ITSRR	The Independent Transport Safety & Reliability Regulator NSW
Knot	Unit of speed - one nautical mile per hour - about 1.85 km/h.
kW	Kilowatt
Lloyds	One of the international ship classification societies. Ship Classification is a system for safeguarding life, property and the environment at sea. Society approval entails verification of a vessel's criteria against a set of requirements during its design, construction and operation for purposes such as insurance.
MCR	Machinery Control Room (a manned space below deck adjoining the vessel's engine room)
NMSC	National Maritime Safety Committee
NSW	New South Wales
OTSI	The Office of Transport Safety Investigations

PTA	*Passenger Transport Act 1990* (NSW)
Port	The left-hand side when facing forward on board a vessel
Public Passenger Service	The carriage of passengers for a fare or other consideration by means of a vessel within New South Wales waterways
RPM	Revolutions, of running equipment and machinery, Per Minute
SOPs	Standard Operating Procedures that are intended to standardise operations within and/or between organisations
Starboard	The right-hand side when facing forward on board a vessel
Stern	Rear area of vessel
SMS	Safety Management System
SFC	Sydney Ferries Corporation
TAA	*Transport Administration Act 1988*
USL Code	Uniform Shipping Laws Code. The current maritime standard applied throughout Australia in respect of safety matters and specifically vessel construction, equipment, crewing and operation
VOM	Vessel Operations Manual. The prime reference, issued by Sydney Ferries Corporation, containing technical information and operating instructions, for each class of ferries.
'X-Y Lever'	Ferry propulsion control devices, fitted at each navigational station console, that set propeller and rudders to provide longitudinal and transverse thrust as ordered by the vessel's master

EXECUTIVE SUMMARY

The Accident

On Thursday 26 May 2005, Sydney Ferries' Freshwater class ferry *Narrabeen* commenced its regular passenger service between Circular Quay and Manly at 06:45am. It subsequently completed three round trips without incident.

At approximately 12:10pm and on its fourth round trip of the day, *Narrabeen* passed to the North of Fort Dennison and entered Sydney Cove, the limit of which is bounded by an imaginary line running between Bennelong Point and Dawes Point, with the Master intending to berth the vessel at No.3 Wharf.

On entering the Sydney Cove limit, the Master found that *Narrabeen* was not responding as expected to his control commands and that he was unable to exercise full control over the vessel. Realising a collision was imminent, he sounded the vessel's whistle continuously until the time at which the vessel's mid bow collided with the North-Eastern corner of No.5 Wharf. Berthed at this wharf was a First Fleet class ferry which was in the process of disembarking its passengers. Fortunately, they were alerted to the impending collision by *Narrabeen*'s whistle and were rapidly evacuated.

At the moment of the collision, the forward flag pole broke and struck a passenger seated outside on the mid-deck. The passenger sustained facial injuries and was evacuated to a hospital.

Narrabeen sustained structural damage to the area of its bow and the hull immediately below. As a result of the damage, ballast water escaped from the vessel. *Narrabeen* was later towed to Sydney Ferries' Balmain shipyard. The floating pontoon at No.5 Wharf was also damaged.

Emergency Response

Staff, intending passengers and members of the public in the vicinity of No. 5 Wharf were alerted to the emergency by the continuous sounding of Narrabeen's whistle (air horn) and were able to either evacuate the pontoon or to take cover and brace themselves in preparation for the impact.

Immediately following the impact with No.5 Wharf, *Narrabeen* was manoeuvred alongside No.3 Wharf. The passengers were evacuated and the vessel was attended to by emergency service personnel. The emergency response was both rapid and effective.

Findings

In relation to those matters prescribed by the Terms of Reference as the principal lines of inquiry, OTSI finds as follows:

Causation. The collision was caused by the combined effects of the following actions and factors:

a. the Master of the *Narrabeen* experienced a loss of steering control as he was preparing for berthing when he inadvertently switched to **Backup** mode, instead of his intended switch from **Sailing** to **Manoeuvring** mode;

b. the Master believed that *Narrabeen's* controls had malfunctioned, despite advice to the contrary from the Engineer, and his ensuing actions to bring the vessel under control further exacerbated the situation, and

c. the design of the bridge control console contributed to, rather than protected against, the potential for incorrect switching.

Emergency Response. The emergency response actions of the crew did not conform with Vessel Operations Manual Instructions (VOM) to the extent that neither the Master nor the Helmsman activated the automatic broadcast system designed to alert passengers to a possible emergency. However, the continuous sounding of the vessel's whistle did alert passengers, crew and people on and in the vicinity of No.5 Wharf to the emergency.

Effectiveness of SFC Risk Management Strategies*.* The following findings indicate limitations in the risk management strategies adopted by Sydney Ferries Corporation:

a. crew actions on the day were not consistent with efficient crew resource management practices;

b. individual performance on the *Narrabeen* indicates there is inadequate cross-checking of functions between crew members, and

c. the design of the bridge console presented risks that were not appreciated by Sydney Ferries.

Other Safety Matters. Other matters arising from the investigation that impact on the safety of ferry operations include the following:

a. The cable providing power to the data recorder had not been adequately secured and as a consequence, the supply of power was interrupted by the collision, with the result that there was no subsequent capture of data.

b. Masters confronted with a loss of control have a limited number of recovery options and even fewer manoeuvre options should that loss of control occur within Sydney Cove given the proximity of the wharves, shoreline and other harbour traffic. Sydney Ferries' Masters would benefit from having a clearly defined range of recovery options and contingency plans, by vessel type, in the event of an emergency within Sydney Cove.

Recommendations

To prevent recurrence of this type of ferry accident, it is recommended that the specified responsible entity undertake the remedial safety action described below:

a. **Sydney Ferries Corporation**

i. Implement and enforce a procedure whereby on approach to a wharf, the Master notifies the Engineer of his/her intention to change mode in preparation for berthing, and the Engineer advises the Master that he/she is ready to take control from the Machinery Control Room (MCR) if directed by the Master.

ii. Assess the benefits and risks associated with installing a system of closed circuit television cameras with clear views fore and aft of the vessel, combined with a monitor which can be viewed by the Engineer from within the MCR.

iii. Sydney Ferries trial all of its vessels to determine a ‘point of no return’ on all final approaches beyond which Masters should be aware that certain courses of recovery action are unavailable to them.

iv. Commission a technical study into the design and layout of the bridge console on the Freshwater class to determine its adequacy, both in physical and cognitive terms, and that any resulting recommendations be considered for their applicability across the remainder of the Sydney Ferries’ fleet.

v. Improve the integrity of the power supply to any data recording devices to ensure that such devices continue to function after a collision.

vi. Improve the capability of the personal computers utilised for data capture, including the adoption where necessary of a level of hard drive redundancy such as RAID level 1 or greater.

b. **NSW Maritime Authority**

i. Monitor crew resource management within Sydney Ferries.

PART 1 INTRODUCTION

Notification and Response

1.1 At 12:30pm on 26 May 2005, the Office of Transport Safety Investigations (OTSI) Duty Officer was notified by Sydney Ferries Corporation (SFC) that one of its Freshwater class vessels, the *Narrabeen*, had collided with No. 5 Wharf at Circular Quay at approximately 12:20pm.

1.2 Based on the information provided by the reporter, the Chief Investigator directed the deployment of OTSI's Investigating Officers to the incident site.

Initiation of Investigation

1.3 As a result of the primary evidence collected by the OTSI Investigating Officers at the incident site, the Chief Investigator initiated a Ferry Safety Investigation in accordance with s46B of the *Passenger Transport Act 1990.*

1.4 On 27 May, the Chief Investigator notified all Directly Involved Parties (DIP) that OTSI was investigating the collision and requested that an officer be nominated in each organisation to act as the point of contact for all inquiries made by the appointed OTSI Investigator in Charge. The Terms of Reference for the Investigation were provided to the DIPs with this notification.

Terms of Reference

1.5 The Chief Investigator established the following Terms of Reference to determine why the accident had occurred and what to do to prevent recurrence:

a. identify the factors, both primary and contributory, which caused the accident;
b. identify whether the accident might have been anticipated and assess the effectiveness of any strategies that were in place to manage the related risk/s;
c. assess the effectiveness of emergency actions in response to the accident, and
d. advise on any matters arising from the investigation that would enhance the safety of ferry operations.

Interim Factual Statement

1.6 An Interim Factual Statement notifying OTSI's investigation and describing the incident in terms of what had happened was published on the OTSI website on 27 May 2005.

Methodology

1.7 The methodology adopted for this investigation is based on the Incident Cause Analysis Method (ICAM) and involves the process of:

a. Accurate recording of the incident scene through photographs, notes and sketches;
b. Collection of primary physical evidence at the incident site;
c. Collection of witness evidence;
d. Collection of documentary evidence;
e. Collection of other relevant and/or corroborating evidence, including results of technical inspections and/or test results;
f. Analysis and interpretation of evidence;

g. Determination of those factors which:

   i. contributed directly to accident causation;

   ii. contributed indirectly to accident causation, and

   iii. are relevant safety issues but did not contribute to accident causation;

h. Establishing the cause of the accident, and

i. Determining recommendations to improve safety and prevent recurrence.

1.8 The underlying feature of the methodology is the Just Culture principle with its focus on safety outcomes rather than the apportioning of blame or liability.

Consultation

1.9 On 14 February 2006, a copy of the investigation Draft Report was forwarded to the Sydney Ferries Corporation, the NSW Maritime Authority and the Independent Transport Safety and Reliability Regulator (ITSRR). The purpose was to provide all DIPs with the opportunity to contribute to the compilation of this Final Report by verifying the factual information, scrutinising the analysis, findings and recommendations, and providing any commentary that would enhance the structure, substance, integrity and resilience of the Investigation Report. DIPs were requested to submit their comments by 3 March 2006. Submissions were received from all of the DIPs.

1.10 The Chief Investigator considered all representations made by DIPs and where appropriate, reflected their advice in this Final Report. On 22 March 2006, the Chief Investigator informed DIPs which matters from their submissions had been incorporated in this Final Report and where any proposal was excluded, the reasons for doing so.

Investigation Report

1.11 This report describes the collision which occurred at No. 5 Wharf at Circular Quay on 26 May 2005 and explains why it occurred. The recommendations that are made are designed to contribute to the maintenance of safe ferry operations and to minimise the potential for a recurrence of this type of accident.

PART 2 FACTUAL INFORMATION

Before the Collision

2.1 *Narrabeen* completed three round trips between Circular Quay and Manly on the morning of Thursday 26 May 2005 without incident. Just prior to reaching Sydney Cove on its fourth round trip, the Master relieved the Helmsman at the controls in accordance with normal procedures in preparation for berthing.

Collision Sequence

2.2 The Master reported that he switched from **Sailing** mode to **Manoeuvring** mode as he entered Sydney Cove but that *Narrabeen* failed to respond to his commands. He was contacted by the Engineer who queried why the vessel had been placed into **Backup** mode. The Master responded by advising the Engineer that *Narrabeen* had been placed into **Manoeuvring** mode, not **Backup** mode, and that he was experiencing control system problems.

2.3 The Master became confused when *Narrabeen* failed to respond to his commands. Drawing on his experience, he attempted a number of counter-controls, but was unable to stop the vessel before it collided with the North-Eastern tip of No. 5 Wharf, just metres away from a berthed First Fleet class ferry in the process of disembarking and evacuating its passengers.

2.4 CCTV footage shows prop wash at the stern propeller approximately five seconds before impact, accompanied by funnel smoke, which is consistent with an application of reverse thrust and an increase in engine load / speed. The reverse thrust did not arrest the vessel’s momentum and the starboard bulwark struck a pylon and the bow section collided with the floating pontoon. The vessel bounced away from the wharf after impact and eventually responded to the reverse thrust, pulling clear of the wharves. The CCTV footage then shows the vessel manoeuvring alongside No. 3 West Wharf without further incident.

Emergency Response

2.5 Once the Master realised that a collision was imminent, he sounded the vessel's whistle (air horn) continuously. This action effectively alerted the staff and public who were on No.5 Wharf and the attached pontoon, allowing them time to evacuate the pontoon or to take cover and brace themselves for the impending impact.

2.6 Immediately following impact with No.5 Wharf, *Narrabeen* was brought under control by the Master and manoeuvred alongside No.3 Wharf. The passengers were evacuated and the scene was attended by emergency service personnel. The emergency response to the incident was rapid and effective.

2.7 Sydney Ferries informed Harbour Control, relevant emergency services, OTSI and the NSW Maritime Authority of the incident.

Medical and Toxicology Information

2.8 NSW Water Police breath-tested all of *Narrabeen's* six crew members and all tests returned negative results. Crew members were also drug tested in accordance with Sydney Ferries' drug and alcohol policy and the results were again negative.

Property Damage

2.9 *Narrabeen* sustained structural damage to the bow section, including a rupture of the fore peak tank which allowed ballast water to escape. The vessel was examined by divers who established that there were no major breaches of the hull. No.5 Wharf and its floating pontoon were closed to the public to allow a damage assessment, and subsequently repairs, to be conducted. *Figure 1* shows the containment of ballast water around *Narrabeen's* breached hull.

Figure 1: Hull Damage and Spill Containment

Injuries

2.10 A number of passengers complained of falling to the deck upon impact. One passenger was conveyed to hospital for treatment after having been struck in the face by the ferry's flag pole which broke and was thrown rearwards at the moment of collision.

Location Description

2.11 Circular Quay is Sydney's busiest wharf facility. It is located at the Southern end of Sydney Cove and is comprised of five 75m long, pile-supported piers and pontoon wharves, aligned North/South, providing both access and egress to ferry and charter vessel passengers. More than 10 vessel movements may occur in Sydney Cove concurrently and in recent years, there has been an increase both in traffic frequency and the size of vessels operating therein. Significantly, Circular Quay is less than 300 metres wide at its Southern end. The facility's layout, showing *Narrabeen's* final route and the point of collision, is shown at *Figure 2.* The distance from the Sydney Cove limit line to the wharves is approximately 500m.

Figure 2: Aerial View of Circular Quay

Environmental Conditions

2.12 The weather on the day of the collision was fine and clear, with a slight breeze from the South and a temperature of around 15°C. The tide was on the ebb, with the earlier high tide being at 10:13am. There were no environmental factors identified which may have contributed to the collision.

Vessel

2.13 Sydney Ferries operates four Freshwater class vessels: MV *Narrabeen,* MV *Freshwater*, MV *Queenscliff* and MV *Collaroy*. The propulsion and control systems on the first three vessels are almost identical but the *Collaroy* utilises a propulsion system which is unique within the Freshwater class. All four vessels have two main engines which can be used alone or in conjunction, to drive one or both propellers, depending on the mode selected. *Narrabeen's* design specifications are attached at Appendix A.

Data Recording

2.14 *Narrabeen i*s fitted with a Siemens' monitoring system which utilises a combination of digital and analogue signals to enable the Engineer to view, in real time, the operating parameters of the vessel. This related data is streamed into a personal computer (PC) running vessel monitoring software on a Microsoft Windows platform. Trends are recorded in the form of binary data streams, available for later analysis via monitoring software. The PC had a hard disk drive capacity of 10Gb.

Operational Modes

2.15 The vessel is capable of operating in three distinct modes: **Sailing** mode, **Manoeuvring** mode and **Backup** mode, all selected via bridge control or by the Engineer in the MCR.

2.16 **Sailing** mode is selected for the majority of a Freshwater class vessel's journey. In this mode, the power developed by the main engine is directed to the stern propeller to produce thrust. The stern rudder is used to control the vessel's heading. In **Sailing** mode, the bow propeller is feathered and the rudder is locked at 0° (midships). In the feathered state, the blades of the bow propeller are rotated so that they lie in the direction of water flow; as such, the blades flatten out to be almost horizontal, i.e., in line with the propeller shaft. **Sailing** mode provides the most streamlined vessel shape and creates the least drag through the water and is therefore the most efficient mode other than at times when the vessel is required to manoeuvre in a confined area.

2.17 **Manoeuvring** mode is selected when the vessel is required to commence a berthing operation. In this mode, the inactive bow propeller is taken out of feather to a 0° pitch state. The evolution from the feathered state to the 0° pitch state takes approximately 17 seconds, during which time the bow propeller shaft commences to spin due to the force of the water passing over the now pitched propeller blades. Once active, both the stern and bow rudder work in conjunction to enable the vessel to be highly manoeuvrable, including sideways movement which is necessary for berthing. In **Manoeuvring** mode, the bow propeller provides the majority of the reverse thrust and control, with the stern propeller providing the greater forward thrust. *Figure 3* illustrates the utilisation of propellers and rudders in **Sailing** and **Manoeuvring** modes.

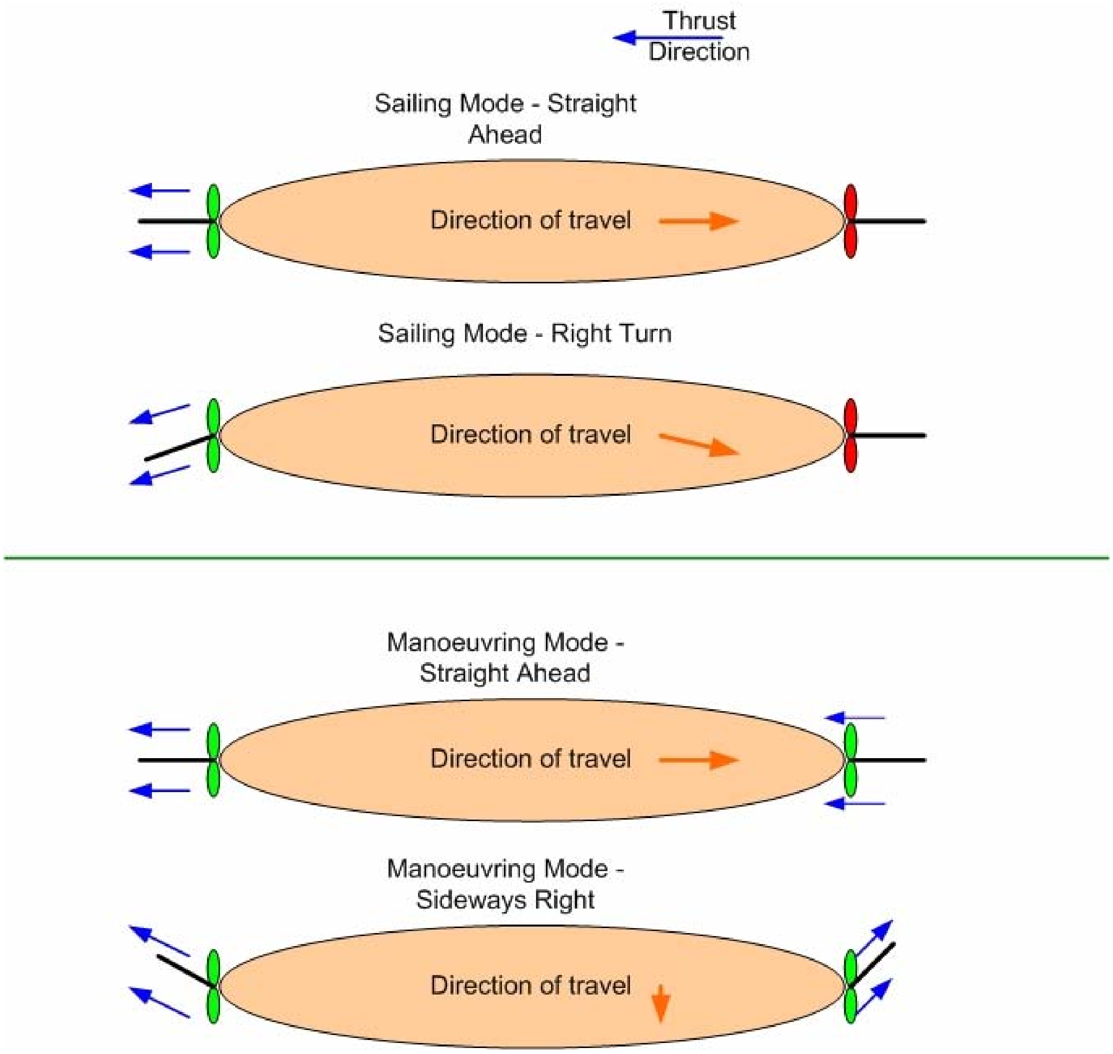


Figure 3: Propulsion Mode Illustration

2.18 A third mode of control is the emergency control mode, identified on the vessel as **Backup** mode. **Backup** mode is utilised when a control failure is experienced, or when controls fail to respond as directed, in either **Sailing** or **Manoeuvring** mode. **Backup** mode offers a level of redundancy which utilises a combination of hard wiring and micro-processor electronics which are separate from the other modes of control. When the vessel is switched to **Backup** mode, it utilises the stern propeller and rudder for control. In **Backup** mode, the normal steering device, known as the X-Y lever and resembling a joystick, is isolated and steering control is effected via a rudder control lever and pitch control levers which are located to the left of the main control console.

Control

2.19 In **Sailing** and **Manoeuvring** modes, the Master controls the direction and speed of the vessel via the X-Y lever and a stern rudder joystick. To turn the vessel, the stern rudder joystick is moved side to side, and to go astern or ahead or increase or decrease speed, the X-Y lever is moved forward or backwards. In **Sailing** mode, vessel direction is controlled by the stern rudder joystick; however in **Manoeuvring** mode, the pitch of both propellers and the angle of both rudders are affected simultaneously by the X-Y lever. If the vessel is in **Sailing** mode and **Backup** mode is selected, control of the vessel is only effected through the stern propeller and rudder, with the X-Y lever being disabled, and pitch and rudder angles are altered via separate controls, as described in paragraph 2.18. If the vessel is in **Manoeuvring** mode and **Backup** mode is selected, pitch and rudder angle at both ends of the vessel can be controlled via independent toggles. *Figure 4* illustrates the function of the X-Y lever.

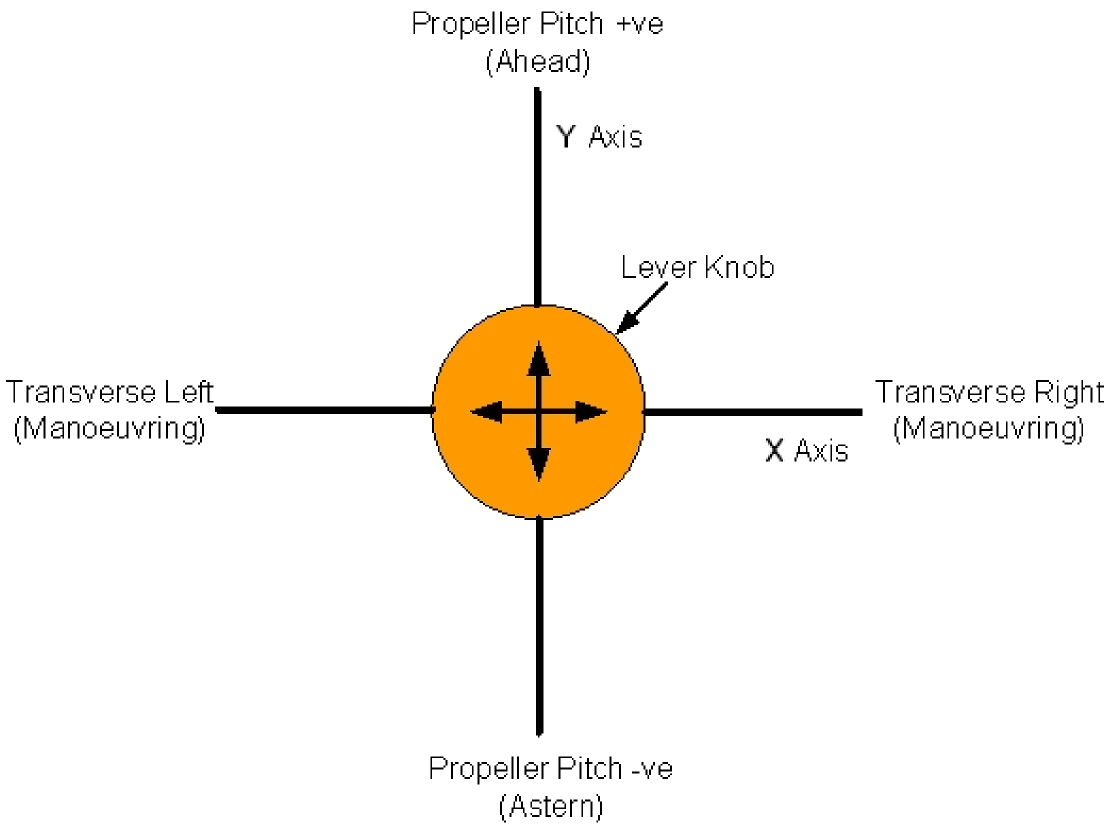


Figure 4: X-Y Lever Function

Crew Information

2.20 At the time of the collision, *Narrabeen* was crewed by six men; the Master, the Engineer, an Engineer's Assistant (more commonly referred to as a Greaser) and three General Purpose Hands (GPHs) who alternate to act as the Helmsman.

2.21 Each member of *Narrabeen's* crew was appropriately qualified and held the relevant certificates of competency. The Master achieved his type-rating on the Freshwater class in 1991. As is usual, the Master was the only person on board holding a Uniform Shipping Laws (USL) Master Class Four qualification, entitling him to exercise navigational command of the vessel. As required under the *Ports Corporatisation and Waterways Management Act 1995* for masters of large vessels, *Narrabeen's* Master held a valid local knowledge certificate.

2.22 *Narrabeen's* Engineer held a Marine Engineer Class 1 qualification, which exceeded the minimum requirement for an Engineer certificate of competency of USL Class Two, and had operated on *Freshwater* class vessels since 1999.

2.23 GPHs, or 'deckhands', do not require a marine certificate of competency, but must obtain an endorsement issued by the NSW Maritime Authority, after qualifying for a Pre-Sea Safety Certificate. *Narrabeen's* GPHs had been appropriately endorsed.

PART 3 ANALYSIS

3.1 When interviewed by OTSI investigators, the Master recounted that *Narrabeen* failed to respond to his commands after he switched from **Sailing** to **Manoeuvring** mode in preparation for berthing and that he was unable to regain control until after the collision.

Failure Analysis

3.2 When interviewed, the Engineer expressed the view that *Narrabeen* had been switched to **Backup** rather than **Manoeuvring** mode and had responded accordingly, prompting his brief communication with the Master regarding the control change.

3.3 On return to the Balmain shipyard, *Narrabeen* was quarantined and all control systems isolated. On the morning of 27 May 2005, the vessel was examined by representatives from OTSI, the NSW Maritime Authority, Sydney Ferries and the manufacturer of the propulsion system, with particular attention to the steering and propulsion systems. No defective components were identified during this examination.

3.4 During the process of examining the data logger, it was identified that the power cable running from the power supply to the PC had become dislodged during the collision. As a consequence, there was no recording of the vessel's operating parameters after the moment of impact. To ensure the integrity of the original data, the hard disk drive was removed from the PC and the data was copied to a new drive. The NSW Police Force's State Electronic Evidence Branch assisted OTSI by ensuring that an exact bit-for-bit copy of the data was captured and at the same time, provided further protection against evidence contamination via the utilisation of a hardware write-blocking device. The state of the hard drive indicated that a thorough regime to back-up data was not in place. OTSI noted that the computer used to capture operating data had been approved by Lloyds Register.

3.5 OTSI is aware that Sydney Ferries is in the final stages of concluding its evaluation of tenders for the supply and installation of new data loggers. OTSI believes that any system incorporating a PC to capture safety-critical data should have, as a minimum, two hard drives configured at RAID (**redundant array of independent drives**) level 1 or higher. This is the first true level of redundancy with disc mirroring, whereby data is simultaneously written to both drives. If one drive fails, another is still capable of recording data. Such an arrangement may also reduce the prospect of data being lost or corrupted during the downloading process. If the roll-out of new data recorders is to occur over an extended period, Sydney Ferries should give consideration to interim measures that may be implemented to address the issues affecting the reliability of its existing data loggers and their related ancillaries.

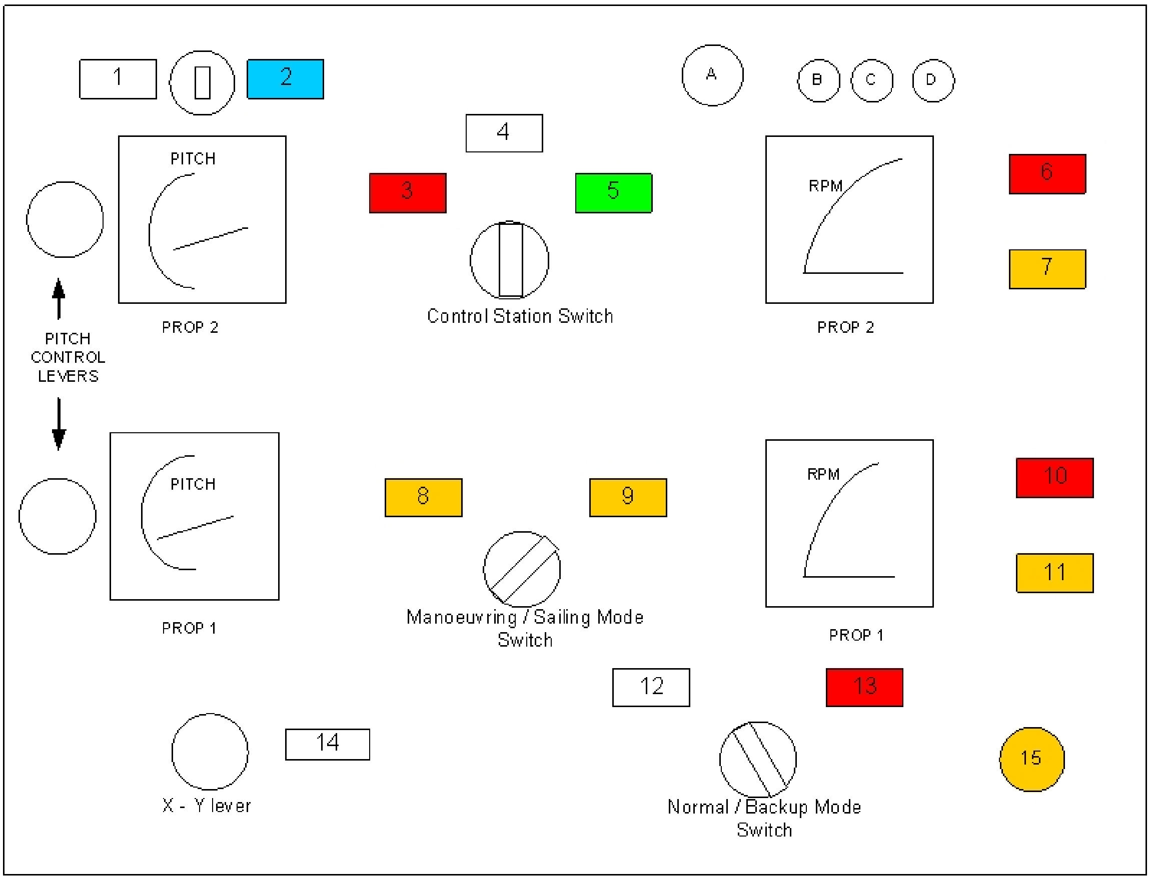
3.6 The data logger recordings taken up until the time of the collision, and the associated loss of power, did not identify any vessel control abnormalities. Later examinations, utilising software test functions, matched the trend pattern associated with switching between **Normal** and **Back-up** modes and supported the scenario of an unintentional switch to **Backup** rather than **Manoeuvring** mode. During a second interview, the Master advised that upon further reflection, he recalled performing the switch from **Sailing** to **Manoeuvring** mode whilst simultaneously checking visually for traffic to his port and rear. He acknowledged that in doing so, he might have accidentally switched the vessel into **Backup** rather than **Manoeuvring** mode. In view of this recollection and the statement by the Engineer, and in the absence of any evidence to suggest otherwise, OTSI concluded that the loss of control was a consequence of human error.

Bridge Design

3.7 Command of *Narrabeen* is normally exercised from either the No. 1 or No. 2 wheel house (or 'bridges'), each of which has, along with a centre control console, a port and starboard wing station for use during berthing. The layout of the centre control console resembles a desk fitted with switches and gauges, angled slightly upwards towards the windscreen. The console runs most of the width of the bridge, with a section either side for floor mounted lookout chairs. *Figure 5* shows a photograph of the main section of the console, comprised of the X-Y lever and mode switches.

Figure 5: Centre Control Console - Main Controls

3.8 *Figure 6* identifies all of the individual controls and indicators. As can be seen in *Figures 5 and 6*, both the **Sailing – Manoeuvring mode** and **Normal – Backup mode** switches are identical in shape and are located in close proximity (17cm) to each other.



Key:

1	Key in accept switch MCR
2	Key in accept switch Bridge
3	Port Wing Station Indicator Lamp
4	Centre Station Indicator Lamp
5	Starboard Wing Station Indicator Lamp
6	Emergency Bow Propeller Stop Switch
7	Bow Propeller Isolator Switch
8	Manoeuvring Mode Indicator Lamp
9	Sailing Mode Indicator Lamp
10	Emergency Stern Propeller Stop Switch
11	Stern Propeller Isolator Switch
12	Normal Mode Indicator Lamp
13	Backup Mode Indicator Lamp
14	X-Y Lever Percentage Indicator Display
15	Whistle Button
A	Lamp Test Button
B,C,D	Dimmer Controls

Figure 6: Centre Control Console – Detailed Layout

3.9 At interview, the Master had difficulty in recalling the direction in which the switches are turned to select between control modes. Given the close proximity of the switches and their identical design, OTSI believes it is possible that these switches might be mistaken or operated in the reverse direction by a Master reaching out and operating the switches whilst he/she was facing away from the control panel. There would be less prospect for such an error if these switches were not identical to each other or had to be operated in different planes.

Master and Crew's Emergency Actions

3.10 The emergency situation developed over a period of approximately one minute, during which time neither the Master nor the Helmsman activated the automated warning system. Instead, the Master relied on the continuous sounding of the whistle and the actions of other crew to warn the passengers on board.

3.11 With the benefit of a clearer understanding of his role and responsibilities, and improved communication by the Master, the Helmsman would have been able to assist the Master throughout his predicament in a variety of ways, e.g., by activating the automated broadcast system; by assisting in the fault-finding process and by relaying communications between the Master and the crew.

3.12 The Master advised that the vessel was travelling at approximately 14 knots at the time of the mode switch. Had there been no deceleration thereafter, *Collaroy* would have closed on the wharves at approximately seven metres per second. Given that Sydney Cove's limit line is approximately 500m from the closest wharf, this would have meant that the Master had approximately 71 seconds to deal with the situation. Had there been any deceleration as a consequence of the Master's control instructions, and CCTV footage indicates that there was, this would have extended the response time available to the Master. The CCTV footage indicates that the Master may have had up to 86 seconds in which to arrest Collaroy's momentum but this could not be confirmed with absolute accuracy because of positioning of the cameras relative to the vessel and the wharf, and because the related images were captured on a frame-by-frame basis. Notwithstanding this time differential, it is important to appreciate that the size of the vessel and its associated machinery results in delay between command input and system reaction. The speed of a *Freshwater* class vessel's response to control inputs varies at different settings and is also by factors such as the effects of fluid dynamics and the limitations of hydraulic systems, the starting and stopping of large rotating masses and the windmilling effect on propellers travelling through a body of water. These factors need to be understood by masters as they fundamentally limit a vessel's responsiveness in emergency situations.

3.13 The Master recalls focusing on attempting to arrest *Narrabeen's* momentum through the application of reverse thrust but could not recall precisely the full range or order of actions he attempted to achieve this result. It was apparent to OTSI that this was the Master's sole focus and that at no stage did he accept the Engineer's proposition that the vessel had been switched to Backup mode.

3.14 The GPHs stationed on the main deck acted without being prompted by the Master and managed to secure *Narrabeen* as soon as it reached No.3 Wharf. Thereafter, they supervised the evacuation of passengers.

Organisational Issues – Crew Resource Management (CRM)

3.15 In reviewing the interaction between the Master and the Engineer, OTSI was able to draw parallels with other recent investigations it has conducted into incidents involving Sydney Ferries' vessels. It is clear in this instance that the Master attributed little weight to the advice given by the Engineer. In the other investigations alluded to, there have been instances where there has been no communication between the Master and the Engineer at the onset of, and during, an emergency situation. This is most significant because the Engineer is able to take over control of the propulsion system at its lowest level on the Freshwater class. He/she can directly effect changes to propeller pitch as far down in the propulsion control system as the hydraulic control unit, bypassing all electronic controls and systems. However, the Engineer must be directed by the Master to do so. The Engineer is also heavily reliant upon advice from the Master or Helmsman to maintain his/her situational awareness given that he/she normally operates in the MCR *(see Figure 7)*. In this instance, the level of ambient noise within the MCR was such that the Engineer did not even hear the vessel's whistle being sounded. In the limited time available, without knowing *Narrabeen's* exact position and without receiving further communication from the Master, intervention by the Engineer would not have been an option.

Figure 7: Engineer's Environment

3.16 Upon interview, the Helmsman stated that he did not really appreciate what was occurring on the vessel during the emergency, and admitted to not having a clear understanding of his role on the bridge in emergency situations. He was also unable to recall participating in a drill which simulated the situation he and the Master faced on the day.

3.17 Clearly, all crew members need to be aware of any abnormal operating situation before they can be expected to react to that situation. Ideally, the crew should also have visibility of the Master's recovery plan or intended actions and be able to draw on experience gained during practiced emergency drills. In this instance, the Master did little to encourage further communication from the Engineer and did not communicate with the remainder of the crew. What should have been controlled crew response to the emergency was, in fact, a series of independent actions by the Master and the GPHs, and this was not reflective of good CRM.

Remedial Actions

3.18 In consultation with the NSW Maritime Authority, Sydney Ferries retro-fitted its Freshwater Class vessels with a safety lockout over the Normal – Backup mode switch, as illustrated in *Figure 8.* However it did not change the switch position on the control panel.

Figure 8: Retro-fitted 'Lockout' on Normal-Backup Mode Switch

3.19 Sydney Ferries has also advised that it has commenced upgrading on-board data-recording PCs and has improved, where necessary, the routing and securing of power cables to its data loggers throughout the fleet. It further advised that it has also initiated a formal procedure which requires crews to perform specific actions in preparation to drop anchor in the event of a control emergency.

Organisational Issues – Fatigue & Impairment

3.20 Having examined rosters and work sheets, there was nothing to suggest that fatigue was a contributing factor. The entire crew returned negative results to drug and alcohol testing.

Organisational Issue – Training

3.21 A limiting factor in any emergency preparedness is the depth of the risk assessment carried out on systems and procedures. Sydney Ferries failed to identify the risk of inadvertent switching when utilising identical and closely positioned mode switches. As a consequence, the emergency situation that presented had not been incorporated into any form of emergency drill.

3.22 Having viewed a range of Sydney Ferries' training and operating policy and procedural documents, OTSI noted that there is little reference to the requirement for cross-checks between crew members during normal operations. Systems of cross-checking have been utilised in the aviation environment, for example, for many years and provide an added layer of defence against error, inaction or poor situational awareness. Such systems also promote a team-based safety culture.

3.23 During the examination of Sydney Ferries' approach to competency and emergency training over a number of investigations, limitations in the programming and content of training and its design, delivery and evaluation have become apparent. OTSI has not pursued these limitations in this report, but will do so in the context of a systemic investigation into collisions across the Freshwater class that is currently in progress.

PART 4 FINDINGS

Findings

4.1 In relation to those matters prescribed by the Terms of Reference as the principal lines of inquiry, OTSI finds as follows:

4.1.1 ***Causation.*** The collision was caused by the combined effects of the following actions and factors:

a. the Master of the *Narrabeen* experienced a loss of steering control as he was preparing for berthing when he inadvertently switched to **Backup** mode, instead of his intended switch from **Sailing** to **Manoeuvring** mode;

b. the Master believed that *Narrabeen's* controls had malfunctioned, despite advice to the contrary from the Engineer, and his ensuing actions to bring the vessel under control further exacerbated the situation, and

c. the design of the bridge control console contributed to, rather than protected against, the potential for incorrect switching.

4.1.2 ***Emergency Response***. The emergency response actions of the crew did not conform with Vessel Operations Manual Instructions (VOM) to the extent that neither the Master nor the Helmsman activated the automatic broadcast system designed to alert passengers to a possible emergency. However, the continuous sounding of the vessel's whistle did alert passengers, crew and people on and in the vicinity of No.5 Wharf to the emergency.

4.1.3 ***Effectiveness of SFC Risk Management Strategies****.* The following findings indicate limitations in the risk management strategies adopted by Sydney Ferries Corporation:

a. crew actions on the day were not consistent with efficient crew resource management practices;

b. individual performance on the *Narrabeen* indicates there is inadequate cross-checking of functions between crew members, and

c. the design of the bridge console presented risks that were not appreciated by Sydney Ferries.

4.1.4 ***Other Safety Matters***. Other matters arising from the investigation that impact on the safety of ferry operations include the following:

a. the cable providing power to the data recorder had not been adequately secured and as a consequence, the supply of power was interrupted by the collision, with the result that there was no subsequent capture of data, and

b. Masters confronted with a loss of control have a limited number of recovery options and even fewer manoeuvre options should that loss of control occur within Sydney Cove given the proximity of the wharves, shoreline and other harbour traffic. Sydney Ferries' Masters would benefit from having a clearly defined range of recovery options and contingency plans, by vessel type, in the event of an emergency within Sydney Cove.

PART 5 RECOMMENDATIONS

5.1 To prevent recurrence of this type of ferry accident, it is recommended that the specified responsible entity undertake the remedial safety action described below:

5.1.1 Sydney Ferries Corporation

a. Implement and enforce a procedure whereby on approach to a wharf, the Master notifies the Engineer of his/her intention to change mode in preparation for berthing, and the Engineer advises the Master that he/she is ready to take control from the Machinery Control Room (MCR) if directed by the Master.

b. Assess the benefits and risks associated with installing a system of closed circuit television cameras with clear views fore and aft of the vessel, combined with a monitor which can be viewed by the Engineer from within the MCR.

c. Sydney Ferries trial all of its vessels to determine a 'point of no return' on all final approaches beyond which Masters should be aware that certain courses of recovery action are unavailable to them.

d. Commission a technical study into the design and layout of the bridge console on the Freshwater class to determine its adequacy, both in physical and cognitive terms, and that any resulting recommendations be considered for their applicability across the remainder of Sydney Ferries' fleet.

e. Improve the integrity of the power supply to any data recording devices to ensure that such devices continue to function after a collision.

f. Improve the capability of the personal computers utilised for data capture, including the adoption where necessary of a level of hard drive redundancy such as RAID level 1 or greater.

5.1.2 NSW Maritime Authority

a. Monitor crew resource management within Sydney Ferries.

Appendix A – MV Narrabeen

Narrabeen was built at the State Dockyard (Carrington Slipway) in Newcastle NSW between 1982 and 1984 and is capable of carrying up to 1,100 passengers, with seating for 815.

Narrabeen, *Queenscliff*, *Freshwater* and *Collaroy* make up the Freshwater fleet of vessels operated by Sydney Ferries. All Freshwater class vessels are double-ended monohulls, comprising of a steel hull and an aluminium upper superstructure.

Narrabeen is 70.4m long and 12.4m wide and has a displacement of 1,140 tonnes and a draft of 3.35m. As with all Freshwater class vessels, *Narrabeen* is powered by two Daihatsu marine diesel engines, each producing 2,338kw, which drive variable pitch propellers via a series of clutches and gearboxes.

Narrabeen is surveyed under NSW Maritime Authority class 1D and Lloyds' classification permit number NSW 15528.

Figure 9: Narrabeen enroute from Sydney Cove to Manly