FERRY SAFETY INVESTIGATION REPORT

FERRY *PEMULWUY* LOSS OF CONTROL

SYDNEY HARBOUR, NSW

2 JULY & 23 NOVEMBER 2020

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Cover photo: Ferry *Pemulwuy*
Source: OTSI

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THE OFFICE OF TRANSPORT SAFETY INVESTIGATIONS

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

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Once OTSI has completed an investigation, its report is provided to the NSW Minister for Transport and Roads for tabling in Parliament. The Minister is required to table the report in both Houses of the NSW Parliament within seven days of receiving it. Following tabling, the report is published on OTSI's website at www.otsi.nsw.gov.au.

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On Thursday 2 July 2020, ferry *Pemulwuy* was returning to Circular Quay from Rose Bay when it experienced a loss of primary steering control. The loss of control resulted in a sudden and unexpected turn to starboard at full speed. The turn placed the ferry in the intended path of the following ferry *Narrabeen*, before *Pemulwuy's* master switched to back-up steering and manoeuvred the ferry into safe water.

On Monday 23 November 2020, *Pemulwuy* experienced a second, almost identical loss of control. This also resulted in a sudden and unexpected turn to starboard. The second incident occurred while *Pemulwuy* was travelling to the east near Garden Island, on this occasion there were no vessels in the immediate vicinity.

There were no injuries or damage reported from either incident.

The OTSI investigation found that the amount of current flowing through *Pemulwuy's* steering toggles, likely caused premature deterioration of the toggle switch block contacts. This deterioration considerably shortened the stated service life of the switch blocks and resulted in them sending unprompted command signals to the rudders.

It was also found that the switch block service life was not considered or included in the Transdev Sydney Ferries asset management plan for the Emerald class ferries.

The potential for deterioration of the toggle switches from higher than recommended current flow was not identified by the designer, builder or during plan approval checks carried out by the regulator.

The investigation report makes recommendations to improve asset management of safety critical systems and incident reporting.

Full details of the Findings and Recommendations of this ferry safety investigation are contained in Parts 3 and 4 respectively.

PART 1 FACTUAL INFORMATION

Introduction

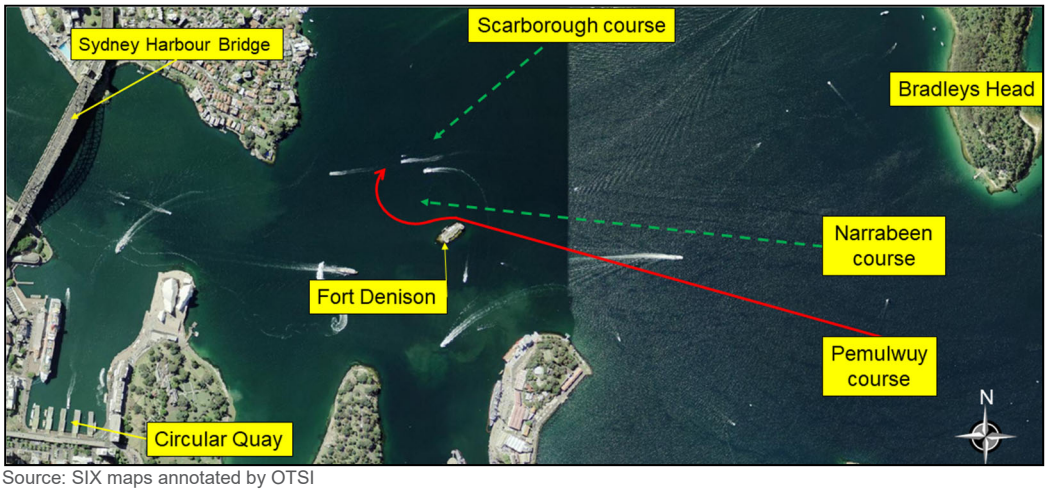
1.1 At approximately 1609[1] on Thursday 2 July 2020, the high-speed passenger ferry *Pemulwuy,* experienced an uncontrolled turn to starboard[2] near Fort Denison. At the time *Pemulwuy* was returning to Circular Quay from Rose Bay on a regular scheduled passenger service.

1.2 *Pemulwuy* had recently overtaken the ferry *Narrabeen* and sailed adjacent to Fort Denison, when the steering stopped responding to the master's command input. The loss of control resulted in both rudders turning hard to starboard.

1.3 As a result, *Pemulwuy* turned across *Narrabeen's* bow from port[3] to starboard, before the master could regain control and bring the vessel to a stop. The master of a third ferry, *Scarborough*, altered course when they saw that *Pemulwuy* had stopped in their intended path.

Location

1.4 The incident occurred in the main inbound shipping channel on Sydney Harbour within Port Jackson (see *Figure 1*).



Source: SIX maps annotated by OTSI

Figure 1: Incident location Sydney Harbour

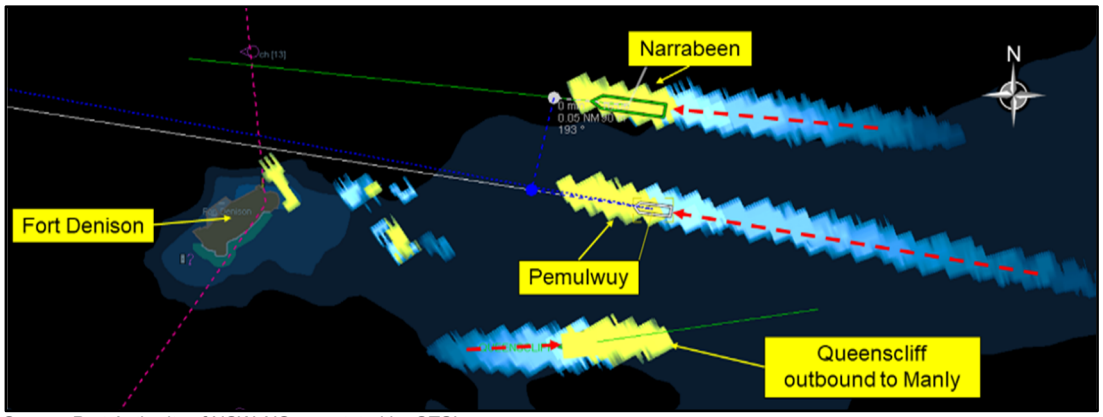
1 Times for the July incident are in 24-hour clock form in Australian Eastern Standard Time.
2 Starboard is the right side of a vessel when viewed from behind.
3 Port is the left side of a vessel when viewed from behind.

2 July 2020 incident

1.5 At approximately 1558 on Thursday 2 July 2020, *Pemulwuy,* a high-speed ferry with a passenger capacity of 400 persons, departed Rose Bay wharf on a journey to Circular Quay. A short time earlier, at 1545 *Narrabeen,* a larger 1100 passenger double-ended ferry, departed Manly Wharf also bound for Circular Quay.

1.6 At approximately 1606, both vessels were on a westerly course, approaching Fort Denison from the east (see *Figure 2*). At the same time, the ferry *Scarborough* approached the vicinity of Fort Denison from the northeast.

1.7 *Pemulwuy,* travelling at approximately 23 knots[4], drew adjacent to, and then overtook *Narrabeen,* which was making approximately 13.5 knots. *Pemulwuy* passed *Narrabeen's* port side, with a closest point of approach of approximately 80 metres. As *Pemulwuy* passed *Narrabeen*, an outbound ferry, *Queenscliff*, sailed in the opposite direction to the south of both vessels (see *Figure 2*).



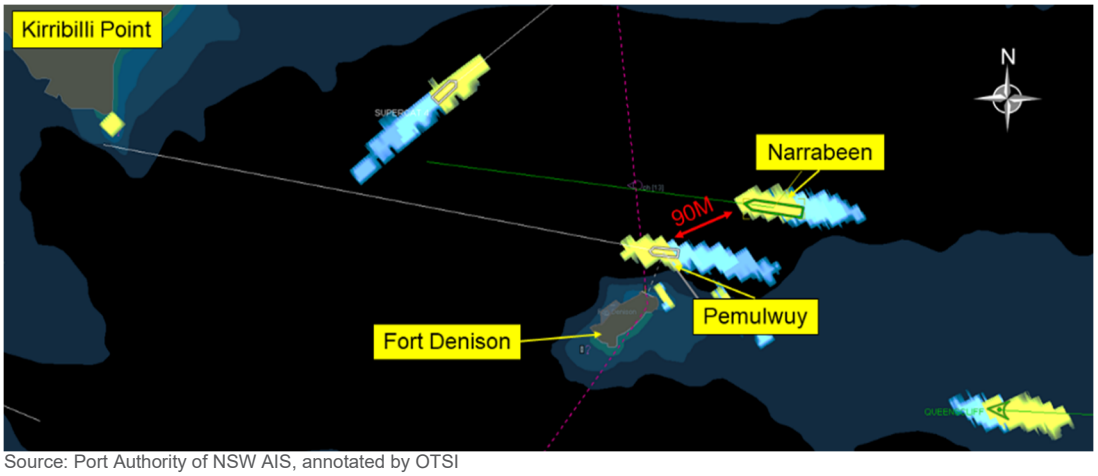
Source: Port Authority of NSW AIS, annotated by OTSI

Figure 2: Automatic Identification System (AIS[5]) image of *Pemulwuy* overtaking *Narrabeen*

1.8 At 1607, *Pemulwuy* passed to the north of Fort Denison, clearing the island by approximately 50 metres. As *Pemulwuy* passed Fort Denison, *Narrabeen* was behind and approximately 90 metres to the northeast (see *Figure 3*).

4 A knot is a unit of speed equal to one nautical mile per hour, or 1.852 km/h.

5 Automatic Identification Systems (AIS) are an automatic tracking system used on ships for identifying and locating vessels by electronically exchanging data with other nearby ships and AIS base stations. AIS information is relayed to other vessels and shore based stations by transponder sending a GPS signal. AIS supplements marine radar as an aid to navigation.



Source: Port Authority of NSW AIS, annotated by OTSI

Figure 3: *Pemulwuy* passing Fort Denison

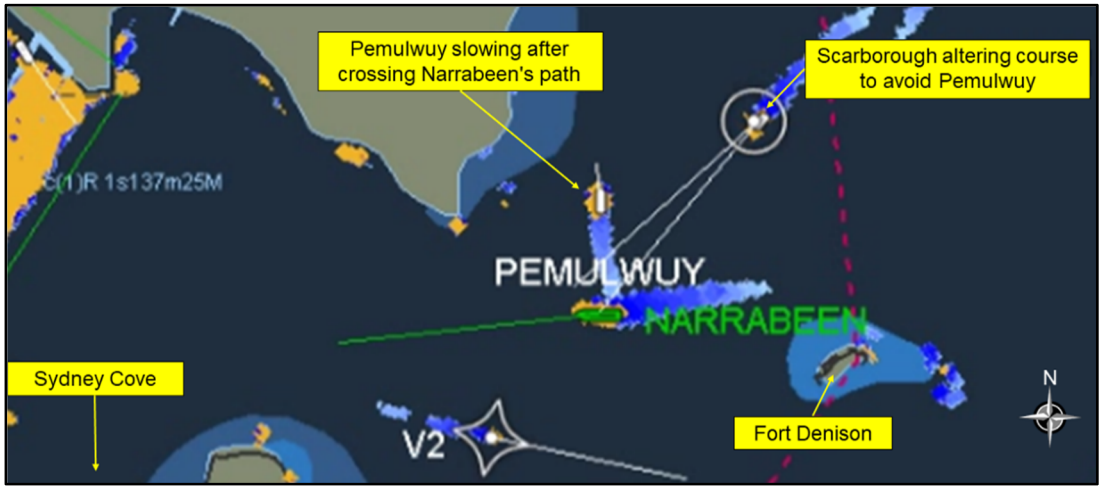
1.9 Approximately 25 seconds after *Pemulwuy* passed Fort Denison, the steering stopped responding to the master's input and both its rudders turned hard to starboard. This resulted in *Pemulwuy* performing an uncontrolled, sudden and unexpected turn to starboard before the master could slow the vessel and switch to back-up steering control.

1.10 The uncontrolled change of heading and subsequent reduction of headway placed *Pemulwuy* in the direct path of the ferry *Narrabeen* (see *Figure 4*). AIS data indicated that *Pemulwuy* slowed to approximately 10 knots, before accelerating to approximately 16 knots for a short distance. This acceleration resulted in *Pemulwuy* clearing *Narrabeen's* intended path. During the turn to starboard, *Pemulwuy* changed course from approximately 260˚ to 359˚.

Source: Port Authority of NSW AIS annotated by OTSI

Figure 4: *Pemulwuy* crossing *Narrabeen's* bow

1.11 When *Pemulwuy's* master realised the vessel was not responding to steering input, he slowed the vessel by reducing power on the throttles. The master then regained steering control by switching to back-up steering and increased power on the throttles, which allowed *Pemulwuy* to travel a short distance so as to clear *Narrabeen's* path. The master then set the engine throttles to neutral and confirmed the back-up steering control was operational. This resulted in *Pemulwuy* drifting a short distance to the north of *Narrabeen's* path and ahead of the ferry *Scarborough*, which was approaching from the northeast. *Scarborough's* master seeing *Pemulwuy* in their intended path, altered course to pass down *Pemulwuy's* starboard side at a safe distance (see *Figure 5*).



Source: Port Authority of NSW AIS annotated by OTSI

Figure 5: *Scarborough* altering course to avoid the slowing *Pemulwuy*

1.12 *Narrabeen's* master reported that when he noticed *Pemulwuy* turn across his bow, he reached for the controls to avoid a collision. However, before he could actually respond, *Pemulwuy* had reaccelerated and moved out of *Narrabeen's* path.

1.13 *Pemulwuy's* master ensured that the vessel was safe and then made a passenger announcement on the vessel's public address system. The general purpose hand (GPH), conducted a patrol of the vessel to reassure and check on the passengers' wellbeing.

1.14 The master and engineer then undertook a series of checks to identify and isolate the problem. They suspected that the steering toggle on the master's seat armrest was faulty (see *Figure 6*).

Source: OTSI

Figure 6: Master's seat and control toggle

1.15 The master tested the controls and confirmed that *Pemulwuy* was safe to manoeuvre. *Pemulwuy* was then navigated to Sydney Cove at reduced speed and berthed at 5-west pontoon Circular Quay. Once at the wharf, passengers disembarked and a Transdev Sydney Ferries (TSF) technician attended the vessel.

1.16 The technician diagnosed the fault during testing as a faulty switch within the toggle assembly. They replaced the toggle assembly, confirmed it was working and then with the aid of a marine crew, took the vessel on sea trials.[6] The approximately 30 minute test confirmed that the steering controls were working correctly.

1.17 *Pemulwuy* re-commenced passenger services at 1735 and operated without further issue for the remainder of the day's shift.

1.18 TSF conducted no further investigation to ascertain the cause of the faulty toggle and discarded it. TSF did not report the incident to authorities.

6 A nautical term describing a trip where the functional testing of a vessel is carried out verifying correct operation of its systems.

Environmental information

1.19 The afternoon of 2 July 2020 was clear and dry, with good visibility. The Bureau of Meteorology recorded a temperature of 22°C at 1500 at the Western Wedding Cake, Sydney Harbour. The wind was moderate from the north-northwest.

1.20 OTSI determined it was unlikely that environmental conditions contributed to the incident.

Vessel information

Source: OTSI

Figure 7: *Pemulwuy*

1.21 *Pemulwuy* was a catamaran type, high-speed passenger ferry, of aluminium construction (see *Figure 7*). The vessel had a measured length of 34.9 metres, a maximum beam[7] of 10.39 metres and a loaded draft[8] of 1.28 metres.

1.22 *Pemulwuy* was in current 1D survey[9] with the Australian Maritime Safety Authority (AMSA) and certified to carry 400 passengers and three crew. It

7 The beam of a vessel is its width at the widest point

8 The vertical distance from the bottom of the keel to the waterline.

9 For an explanation of survey and classes see: https://www.amsa.gov.au/vessels-operators/domestic-commercialvessels/vessel-classes-and-service-categories.

displaced 118 tonnes and was the fourth of six Emerald class ferries to enter the fleet. *Pemulwuy* entered TSF service in August 2017. The ferry had a cruising speed of 26 knots.

1.23 The same steering toggle had been in operation on *Pemulwuy* since the ferry's commissioning.

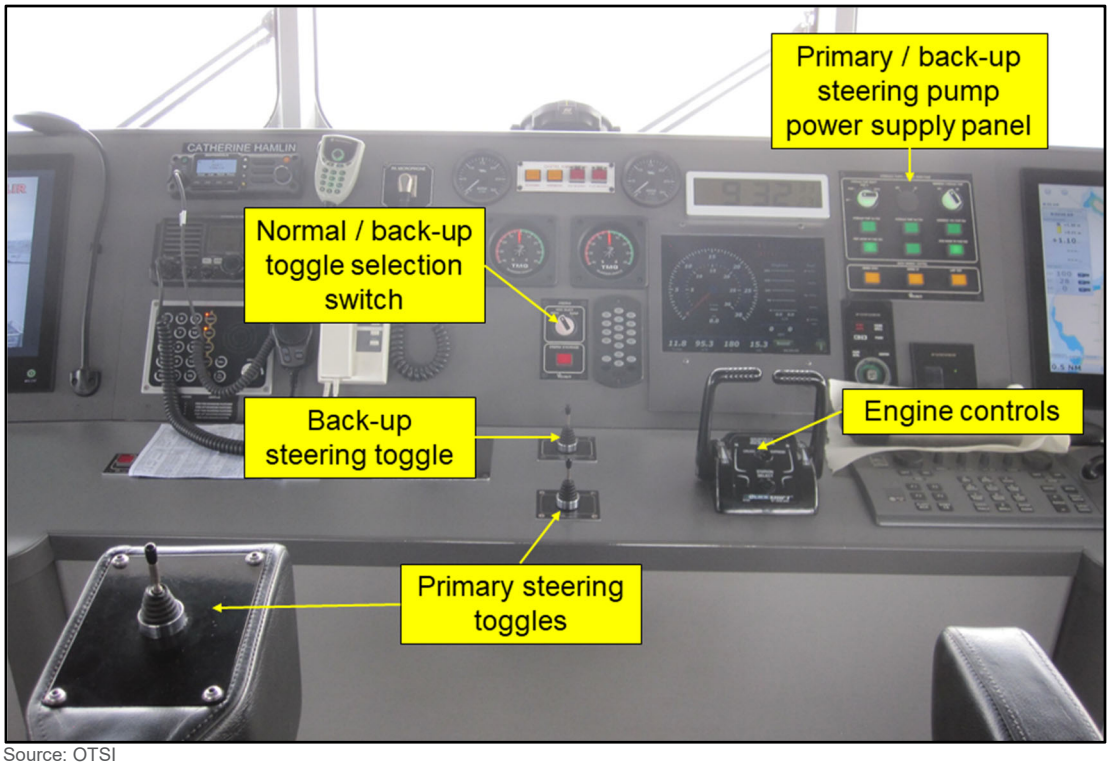
1.24 *Pemulwuy* was powered by two Yanmar 6AYEM-GT marine diesel engines, rated at 749 kW[10] @ 2000 revs per minute. Each engine drove a fixed pitch propeller through a Twin Disc Quick Shift marine gearbox. The vessel had two balanced rudders driven by hydraulics to provide steering.

Pemulwuy steering system

1.25 *Pemulwuy* was controlled from one of three positions in the wheelhouse, the centre helm and two wing stations. All three positions incorporated throttle and steering controls (see *Figure 8*). A fourth steering control was located on the armrest of the master's seat at the centre helm position which allowed the master to navigate while seated. The two wing controls were mainly utilised for berthing operations. These four toggles were on the normal (primary) steering circuit.

1.26 All four primary steering toggles were connected in parallel on a 24-volt direct current (DC) circuit. When the normal steering circuit was selected, a movement of any toggle would alter the rudder angle. As all toggles are active on the circuit, a closed circuit failure of any one, could cause the entire circuit to stop responding.

[10] kW denotes kilowatt, a unit of measurement which in this instance describes the engine output.



Source: OTSI

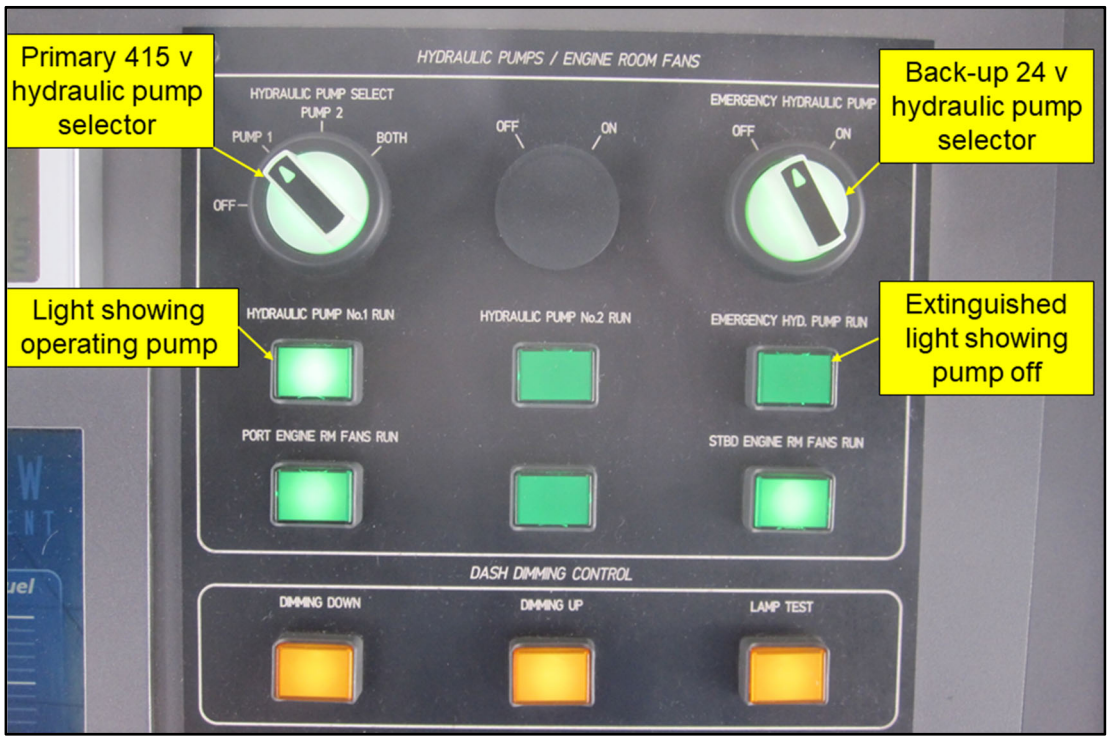
Figure 8: Main control position of an Emerald class vessel

1.27 A back-up steering toggle was located at the centre helm position in case of a failure in the normal steering circuit. This toggle was on a separate 24-volt DC circuit. The master could swap between the normal and back-up steering toggle circuits through a dashboard mounted selector switch (see *Figures 8 & 9*).

Source: OTSI

Figure 9: Primary/back-up toggle selector panel in detail

1.28 In normal operations, two 415-volt alternating current (AC) hydraulic pumps provided power for the steering hydraulics. A separate back-up system, powered by an independent 24-volt DC hydraulic pump, offered redundancy to power the steering system. The activation and selection of primary or back-up power supply was on a panel located on the dash to the right of the main control position (see *Figures 8 & 10*).

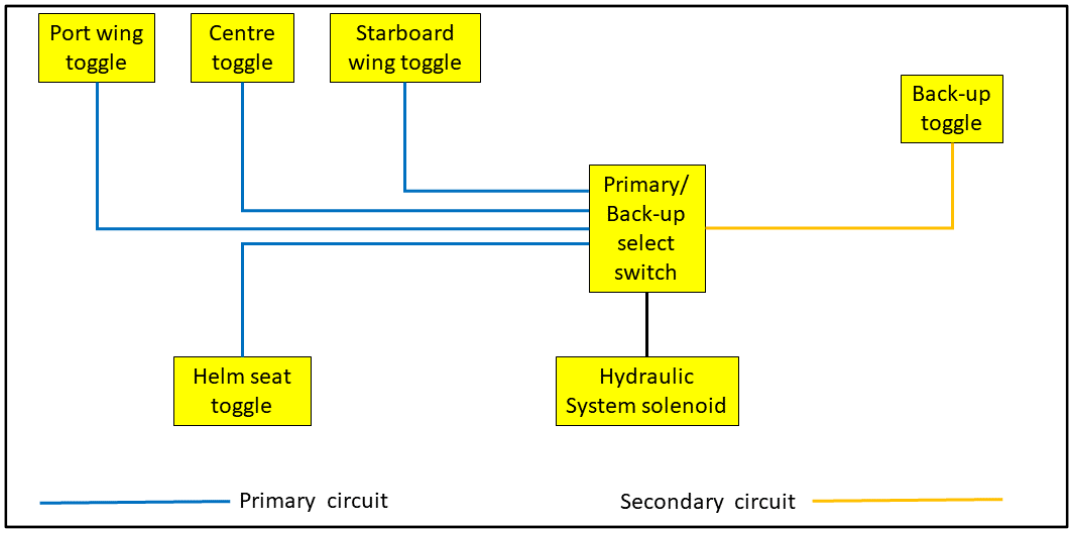


Source: OTSI

Figure 10: Steering power supply panel in detail

1.29 If a master suspected a failure of the primary power supply, activation of the back-up supply consisted of two steps: the main hydraulic pump selector needed to be switched off and then the back-up pump switched on.

1.30 If a master suspected a failure in any of the four primary toggle controllers, they could switch to the back-up steering circuit. This activated the back-up toggle to steer the vessel utilising whichever steering pump was active (see *Figure 11*).



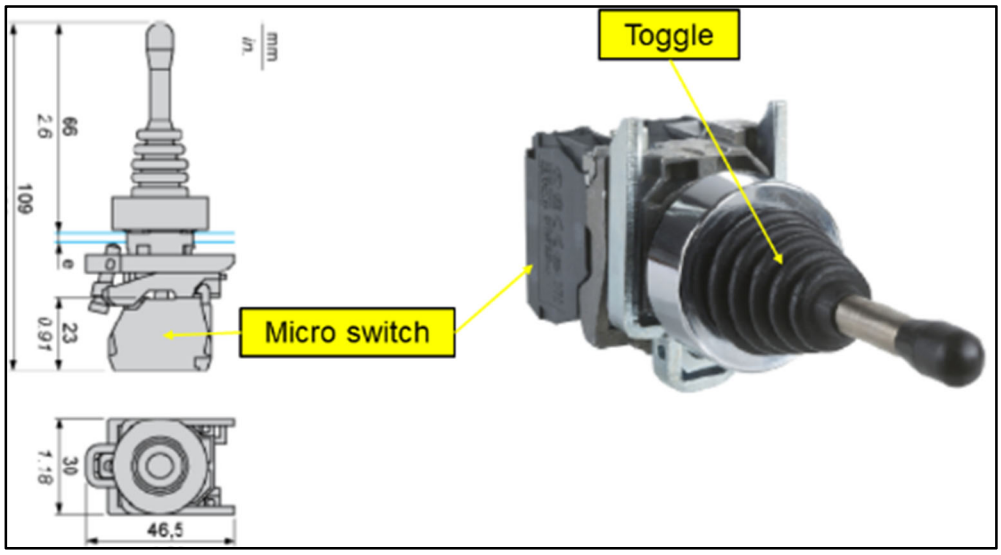
Source: OTSI

Figure 11: Simplified 24V DC steering system

1.31 *Pemulwuy* was equipped with a Vessel Data Recorder System (VDRS) which records and stores important data from the vessel operating systems. This data can be downloaded and used to analyse vessel performance, faults and incidents. *Pemulwuy's* VDRS was not configured to record rudder position or input commands at the time of the incidents. The data was not downloaded following the 2 July incident and was eventually overwritten.

Pemulwuy steering toggles

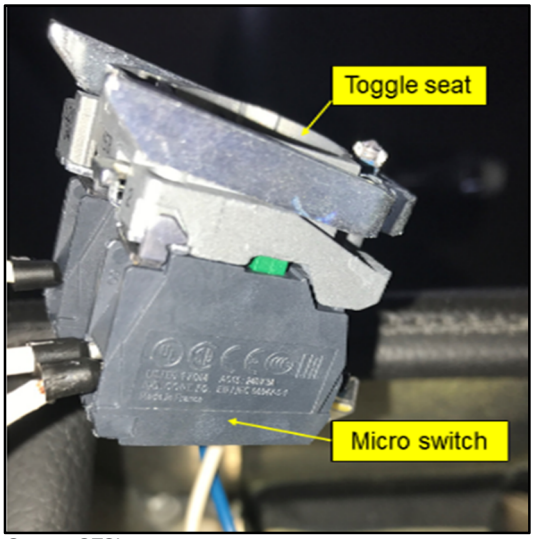
1.32 Schneider Electric manufactured the steering toggles installed on the Emerald class ferries. The toggles were designated as XDPA22 Joystick Controllers (*see Figure 12*).



Source: Schneider, annotated by OTSI

Figure 12: Steering toggles

1.33 The product data sheet stated that the micro switches (see *Figure 13*) had a service life of 1,000,000 cycles on a 24-volt DC circuit, when operated with a 0.5 amp[11] current.



Source: OTSI

Figure 13: Micro switch

1.34 At the 2 July 2020 loss of steering control, *Pemulwuy's* seat toggle had been in service for approximately three years. TSF estimated that the yearly usage of the seat toggle was 250,000 cycles. With this estimation, the toggle would have completed approximately 875,000 cycles at the time it failed.

1.35 TSF had no documented plan for the replacement and maintenance of the steering toggles, which were replaced as they failed.

Source: OTSI

Figure 14: *Narrabeen*

[11] Electric current is the movement of electrons through a wire. Electric current is measured in amperes (amps) and refers to the number of charges that move through the wire per second.

1.36 *Narrabeen* was a 70 metre long double-ended ferry with a 12.5 metre beam and a displacement of 1140 tonnes (see *Figure 14*). The vessel had a passenger capacity of 1100 and a cruising speed of 14 knots.

The crew

1.37 *Pemulwuy* was normally operated with a crew of three: the master, engineer and a GPH. All three crewmembers were in the wheelhouse at the time of the incident.

1.38 The three crew held the appropriate Certificates of Competency[12] issued by AMSA applicable to *Pemulwuy's* operation.

1.39 The master held valid Master <35m and Marine Engine Driver 3 certificates of competency. The master held a valid certificate of local knowledge for Sydney Harbour. Following the successful completion of training, the master was assessed as competent by TSF to command the Emerald class of ferries in December 2018. The master had last conducted emergency drills on the Emerald class in June 2020.

1.40 The engineer held valid Marine Engine Driver 2 and Master <24m certificates and was assessed competent as an engineer for the Emerald class in August 2018. The engineer had also conducted emergency drills on the Emerald class of ferries in June 2020.

1.41 The deckhand held valid Master <24m and GPH certificates and was assessed as competent in the Emerald class in March 2017. The deckhand had last carried out emergency training drills on an Emerald class ferry in April 2020.

1.42 All three crew members were considered current with regard to training/drills under the TSF Safety Management System (SMS).

Transdev Sydney Ferries

1.43 TSF was a business unit of Transdev Australasia. It was the main provider of ferry passenger services on Port Jackson, transporting over 14 million

[12] A Certificate of Competency issued by AMSA shows a seafarer's capability to master a vessel and its passengers. It is a legislative requirement that a seafarer have a Certificate of Competency before they can work on a domestic commercial vessel in Australia.

passengers in 2019. TSF operated regular timetabled ferry commuter services across Port Jackson under contract for Transport for NSW (TfNSW).

1.44 At the time, TSF operated a fleet of 32 ferries of varying classes. The Emerald class consisted of six ferries, which mainly operated an inner harbour service. The Emerald class could also operate on the Manly to Circular Quay service if required subject to weather conditions.

TSF Safety Management System – Emerald Class

1.45 TSF had an established and documented SMS that included several levels of documentation. The operational SMS for the Emerald class ferries comprised of two main documents: the Fleet Generic Operations Manual (FGOM) and the Emerald class Vessel Operating Manual (VOM). When combined, the two manuals provided instructions and procedures for operation of the Emerald class of ferries.

1.46 The FGOM contained procedures and work instructions that applied generically throughout the TSF fleet and shore based operations. Included in the FGOM is section 1.15 Incident Management, which stated that TSF will:

- *Report all incidents and near misses.*
- *Record full details of all incidents and near misses on relevant report forms and capture the details in the SHEQ[13] management system.*
- *Conduct an initial investigation and take immediate corrective actions as necessary.*
- *Notify regulatory bodies as required.*
- *Conduct further investigation of the incident as required.*
- *Implement improvement strategies to prevent recurrence of an incident.*

1.47 The FGOM also included a procedure concerning the VDRS: section 1.16.1 Vessel Incident Instruction. The procedure mandated the downloading of data from the VDRS, by pressing an emergency back-up button on the VDRS unit within 12 hours of an incident occurring. However, TSF has said that this functionality is unavailable on the Emerald class ferries. TSF did not supply a

13 SHEQ: Safety Health Environment and Quality

procedure for the Emerald class of ferry and has acknowledged that is an area for improvement in their SMS.

1.48 The incident was not reported to authorities nor was vessel data downloaded from the VDRS and saved following the incident.

1.49 The individual VOMs contained class specific descriptions and operating instructions. Included in the Emerald class VOM were procedures describing the operation of the steering system in both normal and back-up modes. The procedures included a description of how a master was to change from one mode to the other.

1.50 The SMS also contained a Vessel Emergency Response Plan (VERP), which is specific to an individual class of ferry. The Emerald class VERP was in the form of a laminated flip chart located in the wheelhouse. The steps included stopping the vessel, switching to back-up toggle, confirming the change was successful and informing Sydney Ports Vessel Traffic Service (VTS)[14] of the situation. Except for notification to VTS in the first incident, this procedure was followed by both masters of *Pemulwuy* following the control failures in both of the incidents.

Transport for NSW asset management system

1.51 TfNSW was the lead transport agency of the NSW Government in July and November 2020 whose functions were set out in the *Transport Administration Act 1988* (NSW). These functions included a responsibility for procurement of transport infrastructure, vehicles, rolling stock and vessels.

1.52 In order to discharge this function, TfNSW developed an Asset Management Framework (AMF). Which included:

- a Transport Asset Management Policy
- TfNSW asset management standards
- TfNSW project delivery standards
- TfNSW configuration management and engineering assurance standards.

[14] VTS is provided by the Port Authority of NSW, and utilises VHF channel 13 to manage commercial marine navigation on Sydney Harbour

1.53 These requirements placed obligations on TfNSW to undertake engineering assurance on the infrastructure, vehicles and vessels that it procured. This was achieved through a progressive assurance regime (also known as the configuration management system[15]) that examined assets at various stages of the lifecycle including concept, design, construction, commissioning and operation.

1.54 As assets progressed through these lifecycle stages, permission to continue to operate was granted following completion of corresponding approval gates if the requisite engineering assurance was provided. These approval gates were part of TfNSW's configuration management system.

1.55 This system was overseen by the Asset Standards Authority (ASA). The ASA was an independent body within TfNSW, charged with overseeing the configuration management and asset assurance processes. The ASA has since become known as the Asset Management Branch of TfNSW.

1.56 The Emerald class of vessels were procured after NSW Government announcements in 2014. Configuration management processes were initiated once procurement activity commenced.

1.57 The project to procure the Emerald class of vessels moved through the relevant approval gates and certain safety assurance deliverables were provided to the required level of detail as part of configuration management.

1.58 The content of safety assurance deliverables depended on what was being procured, but generally, these would focus on the key safety risks presented by the asset. For example, it would be reasonable to expect that vessel steering and propulsion systems would feature in the assessment process.

1.59 Decisions on the scope of assessment were known as "Judgements of Significance", and helped to direct the focus of the safety assurance effort.

15 ***Configuration Management (CM)*** is a systems engineering process for establishing and maintaining consistency of an assets performance, functional, and physical attributes with its requirements, design, and operational information throughout its life.

AMSA

1.60 AMSA was a commonwealth statutory authority and corporate commonwealth entity, established under the *Australian Maritime Safety Authority Act 1990* (the AMSA Act) (Cwlth).

1.61 AMSA's principal responsibilities included:

- promoting maritime safety and protection of the marine environment
- preventing ship-sourced pollution in the marine environment
- providing infrastructure to support the safety of navigation in Australian waters
- providing a national search and rescue service to the maritime and aviation sectors
- certification of commercial crew competencies.

1.62 AMSA was responsible for ensuring ferries met minimum safety standards for design and operation. AMSA regulated this process through its survey inspection regime which encompassed vessel design, stability, floatation, navigation and safety equipment.

1.63 Owners and operators of Domestic Commercial Vessels were required to report certain marine incidents to AMSA[16] as soon as reasonably practicable. Upon receiving a marine incident report, AMSA classified them into one of three severity levels, described below:

- ***Very serious incidents*** *include loss of vessel, loss of life (fatalities) due to the operation of the vessel and serious pollution.*
- ***Serious incidents*** *(none of the above) include serious injuries (operational), fire, explosion, collision, grounding, contact, heavy weather damage, ice damage, hull cracking, or suspected hull defect, critical equipment failure (i.e. main engines, steering gear), extensive accommodation damage, severe structural damage (penetration of the hull under water), loss of stability, pollution, and breakdown necessitating towage or shore assistance.*

[16] Sections 88 and 89 of the Marine Safety (Domestic Commercial Vessel) National Law Act 2012, Schedule 1 (National Law) (Cwlth).

- ***Less serious incidents*** *(none of the above) include minor injuries, main engine stoppage for maintenance, minor contact, minor oil spills, and near misses.*

1.64 AMSA received notification of the 2 July 2020 loss of control and resulting close quarters from the master of the *Narrabeen* on 14 July 2020. However, AMSA did not receive notification of the incident from either TSF or *Pemulwuy's* master.

23 November 2020 incident

1.65 At approximately 1020[17] on Monday 23 November 2020, *Pemulwuy* experienced a second uncontrolled loss of steering which resulted in another sudden and unexpected turn to starboard. Visibility was clear, there was little marine traffic and a light westerly breeze was blowing.

1.66 At the time, *Pemulwuy* was travelling from Circular Quay to Rose Bay on a regular passenger service. On-board were 20 passengers, the master, GPH and engineer. The master was operating the vessel from the seat at the centre control station. *Pemulwuy* was travelling at 25 knots and had just passed Fort Denison when both rudders turned hard to starboard without any command input by the master.

1.67 When *Pemulwuy's* master recognised the loss of control, they immediately placed both engine controls to full astern, and then switched the steering control to back-up. Once the ferry slowed to a stop and was safe, the master utilised the back-up toggle to centre the rudders. The master's response during the loss of control followed the procedure described in the VERP.

1.68 The master tested the back-up toggle to confirm that the rudders responded correctly, which they did. The master then switched the steering system controls back to the normal position and the rudders immediately went over to starboard again without command. The master switched the system to back-up again and regained control of the rudders. They repeated this process three times and on each occasion, the rudders performed an uncommanded turn to starboard.

[17] Times for the November incident are in 24-hour clock form in Australian Eastern Daylight Time.

1.69 The master switched the control to back-up and proceeded to Rose Bay at a reduced speed. Upon arrival at Rose Bay wharf, the GPH secured the ferry safely and the engineer and master attempted to diagnose the fault.

1.70 Unable to correct the fault the master withdrew the ferry from service. The engineer removed the toggle from the circuit and *Pemulwuy* was navigated to Barangaroo wharf at reduced speed, where TSF technicians met the vessel. The technicians were unable to replicate the fault.

1.71 TSF management confirmed the withdrawal of *Pemulwuy* from service pending further technical evaluation. TSF reported the loss of control to AMSA following the incident.

PART 2 ANALYSIS

Introduction

2.1 The investigation focused principally on the factors that contributed to the loss of control, the actions of the master, and the organisational response to the incidents.

Pemulwuy's master's actions 2 July 2020

2.2 As *Pemulwuy* overtook *Narrabeen*, it passed between the *Narrabeen* and Fort Denison. *Pemulwuy* passed *Narrabeen* at a distance of approximately 80 metres to starboard and then passed Fort Denison approximately 50 metres to port. Passing at these distances placed *Pemulwuy* in close proximity which could increase the risk of collision in the event of a control failure.

2.3 When the control failure occurred, about 25 seconds after passing Fort Denison, the master responded by slowing the vessel and switching to back-up steering control. The response to the control failure was in accordance with the VERP.

2.4 Once in back-up mode, evidence suggests the master took evasive action to avoid remaining in *Narrabeen's* path and risking a collision. This is supported by the AIS data which shows *Pemulwuy* slowed to 10 knots, and then accelerated to 16 knots before finally stopping. The master's action in increasing speed was necessary to move *Pemulwuy* out of *Narrabeen's* path and into safe water.

2.5 Once *Pemulwuy* was in safe water, the master organised the crew to check on passengers and then contacted TSF controlling officers on the company radio network. The loss of control was not reported to VTS, as per the Harbour Masters Directions[18] and the on-board company VERP.

2.6 On return to Circular Quay, the master lodged a safety report in the TSF management system. The master did not report the loss of steering to AMSA

[18] Section 2.1.32 Harbour Masters Directions, www.portauthoritynsw.com.au

or Transport for NSW. The master did not preserve the VDRS data as required by the TSF SMS.

TSF remedial actions and reporting procedures

2.7 The TSF on call duty manager discussed the incident with the master and reviewed the master's safety report. Following this review, the duty manager did not ask the master for an AMSA incident report and closed the matter. VDRS data was not backed up and preserved, as required by TSF procedures[19] following an incident and the data was eventually overwritten.

2.8 TSF did not report the incident to AMSA or the NSW Minister for Transport and Roads in accordance with its SMS (section 1.15 of the FGOM). At the time, TSF assumed that the incident resulted from a simple component failure and discarded the toggle without carrying out a causal failure analysis. Discarding the toggle prevented any further diagnosis. TSF considered the incident was closed.

2.9 In September 2020, following initiation of an OTSI investigation, TSF commenced its own technical investigation into the steering failure of 2 July 2020. This technical investigation concluded that in high use operation, such as that carried out by Emerald class ferries, a more durable steering toggle might be required.

2.10 The investigation also identified that the established TSF fleet maintenance management program, did not include a specific change-out schedule for the steering toggles based on the manufacturer's recommended life expectancy. The investigation identified that while the Technical Supervisor knew of the manufacturer's 1,000,000 cycle toggle life expectancy, it was not documented in the maintenance program.

2.11 The investigation also identified that TSF had estimated the master's seat toggle usage was approximately 250,000 cycles per year. *Pemulwuy* was commissioned in September 2017. Using this 250,000 cycle estimate, the steering toggles would be nearing the end of their serviceable life at the time of

[19] TSF FGOM section 1.16.1.

the 2 July 2020 incident. This service life was estimated assuming a 0.5 amp loading however the actual loading was 1.2 amps which would have significantly shortened the toggle's service life.

2.12 As a result of the technical investigation, TSF replaced the toggles on all the Emerald class ferries with new toggles of the same type.

2.13 In October 2020, TSF commenced a trial of different toggles to identify if a more suitable make was available.

2.14 TSF also conducted an investigation into the internal and external reporting of incidents. That investigation identified several potential improvements in the handling of the incidents in the future. These included:

- Conducting a risk review of preventative maintenance plans for all safety critical systems in the TSF fleet.
- Updating fleet preventative maintenance plans.
- Reviewing internal incident investigation procedures with a view to ensuring all relevant data is recorded and considered for incidents involving safety critical systems.
- Establishing incident review meetings between operational and maintenance staff.

TSF steering toggle maintenance history

2.15 TSF maintenance records showed that several toggle failures occurred in the Emerald class ferries shortly after they came into service in 2017 and 2018[20]. The builder, Incat Tasmania Pty Ltd (Incat), replaced these toggles under warranty. The cause of the failures was not investigated at the time. TSF maintenance records indicated that there were no further failures or replacement of toggles until April 2020[21], and then following the July 2020 incident.

20 17/11/17 Victor Chang Master's Seat, 27/02/18 Pemulwuy stbd wing, 20/04/18 Victor Chang location not recorded, 3/09/18 Emerald 6 centre console.

21 7/04/20 Fred Hollows stbd wing.

2.16 All of the replaced toggles had malfunctioned within the 1,000,000 cycles durability rating. TSF did not have a planned maintenance replacement program for the toggles which were replaced as they failed.

TSF response to the 23 November 2020 loss of control

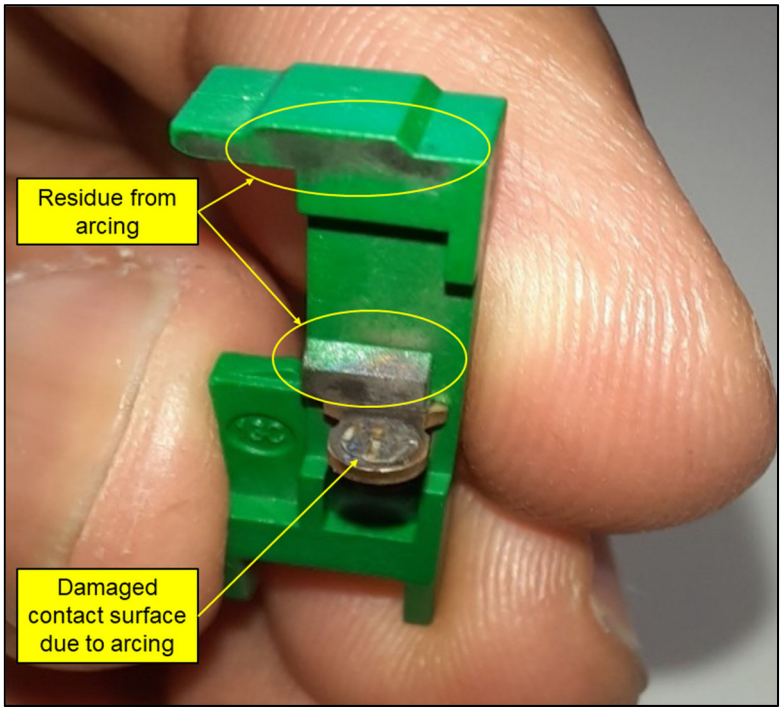
2.17 Observing the similarity of the second loss of control with the earlier incident in July 2020, TSF instigated a second investigation of *Pemulwuy's* steering system.

2.18 This investigation began by confirming the integrity of the electrical wiring in the wheelhouse toggle steering system. Unable to locate any fault within the steering system wiring, TSF contacted Incat for assistance in fault diagnosis. Incat provided a technician who was originally involved in the design and installation of the Emerald class steering system. This technician attended the vessel and assisted TSF with fault diagnosis. TSF also contacted Schneider Electrics to assist with providing information about the toggles during the investigation.

2.19 The investigation identified that the steering toggle (XDPA22 Joystick Controllers) micro switches, as installed from new, were not carrying 0.5 amps as assumed, but exposed to an electrical current of 1.2 amps. This current was at the upper limit of the carrying capacity of the switch and almost two and a half times over the stated manufacturer's durability rating. TSF contacted Schneider and reported the current that was measured during the investigation. Schneider estimated, that under those operating conditions, the durability rating would reduce by a factor of ten, to approximately 100,000 cycles.

2.20 The toggle from the second incident was installed 13 days prior to the incident. TSF was unable to identify a causal failure and hypothesised that a manufacturing fault may have caused the premature failure.

2.21 Following the second incident, TSF conducted destructive testing of the micro switches removed from the Emerald class ferries. This testing found that the contact surfaces were pitted and charred (see *Figure 16*).



Source: TSF, annotated by OTSI

Figure 15: Damaged micro switch surface

2.22 The investigation determined that the switches were operating at the upper limit of their current carrying capacity. This likely resulted in pitting and charring, caused by arcing between the contact surfaces on the micro switch. The damage to the contact surfaces likely resulted in both short and open circuit faults[22].

2.23 TSF, in conjunction with Incat, installed solid-state relays to reduce the current passing through the micro switches to approximately 12 milliamps (0.012 amps). This current was well within the micro switch carrying capacity.

2.24 Following a successful trial of *Pemulwuy* in the new configuration, the relays were installed on all Emerald class ferries by 20 December 2020.

2.25 As a further precaution, TSF replaced all the micro switch blocks on the remaining Emerald class ferry steering toggles.

22 Open circuits where damage prevented proper contact, failing to send master's input commands. Short circuit where high heat momentarily fused surfaces and sent unwanted commands.

AMSA response to the incidents

2.26 AMSA did not receive an initial report of the loss of control from TSF or *Pemulwuy's* master. However, *Pemulwuy's* master had reported the loss of control to TSF on 2 July 2020.

2.27 AMSA became aware of the loss of control when *Narrabeen's* master reported the incident on 14 July 2020. Upon receiving the report of the loss of steering control from *Narrabeen's* master, AMSA classified it as a less serious incident. However, according to AMSA's incident classifications, a loss of steering is a serious incident (refer to paragraph 1.63).

2.28 AMSA then contacted the *Narrabeen's* master to discuss *Pemulwuy's* loss of control and subsequent close quarters event. Following this discussion, the classification remained as a less serious incident. AMSA advised it assessed the first control failure as a maintenance issue and closed the matter.

2.29 AMSA indicated in correspondence received by OTSI on 1 September 2020 that it was working with TSF to improve reporting of incidents.

2.30 On 23 November 2020, AMSA received a report of the second control failure from TSF. At the date of the tabling of this report, OTSI had yet to be advised of what actions AMSA undertook following the receipt of the 23 November 2020 notification.

TfNSW asset management framework

2.31 Procurement of public transport vessels and vehicles was governed by the TfNSW AMF. This framework included requirements for assurance to be provided by the designers and constructors at specified stages of a procurement project. These stages corresponded to the asset lifecycle for safety critical components of the vessel.

2.32 At the time of the Emerald class procurement, the assurance process did not specify which components of the vessel would be required to go through lifecycle approval gates. However, the general requirement was that a decision on those components would be made on the basis of risk. The steering system of a vessel would reasonably be expected to be included in this process. From

the evidence obtained during the investigation, it was likely that during the assurance processes, the steering system was not examined in sufficient depth to consider the impact of current flow on the steering toggle switches.

2.33 The Emerald class procurement project was delivered within the TfNSW supply chain model. In this model, an Authorised Engineering Organisation (AEO) was assessed by TfNSW on its ability to meet the procurement process, and if successful, was approved to build and deliver TfNSW assets. The selection of the AEO for the Emerald class procurement was based on whether the AEO's technical and other systems were deemed suitable and capable to deliver the project to the required standard including possessing suitable industry technical expertise.

2.34 The TfNSW project team also had marine technical expertise embedded within to assist in the delivery of the project. However it was not clear from the evidence if this expertise was used to examine the impact of the amount of current supplied to the steering toggle switch.

2.35 Based on the safety assurance information provided by TfNSW as part of the investigation, it is not clear what level of attention was paid to the wiring arrangements of the steering toggle micro switch.

2.36 There is also no evidence that this type of failure mode, i.e., higher than anticipated current being fed through the switch, was contemplated or identified as part of the risk management processes conducted for the project. This meant that the latent condition of the current being fed through the micro switch lay undetected through design, construction and commissioning. The condition was not discovered until after the November 2020 incident.

2.37 The period when this vessel was being procured (2015-2017), was relatively early in the implementation of the TfNSW AMF for marine projects. The AMF stemmed from the rail reforms under the 'Fixing the Trains' program of 2011-2013. These reforms resulted in the establishment of Sydney Trains and the creation of the ASA in TfNSW. The independent ASA, was originally charged with delivering asset assurance and configuration management for heavy rail, with its remit subsequently expanded to incorporate all modes of passenger

transport. During the time of the procurement for the Emerald class vessels, the application to maritime asset procurement was not as mature or well developed as it was for heavy rail. It is reasonable to expect that as a result, it may not have been as effectively embedded in the marine mode.

PART 3 FINDINGS

3.1 From the available evidence, the following findings are made with respect to the *Pemulwuy* loss of control incidents on 2 July 2020 and 23 November 2020

Contributory Factors

3.2 A failure in the master's seat steering toggle control caused the loss of control of the *Pemulwuy* on 2 July and 23 November 2020.

3.3 A 1.2 amp current passing through the steering toggles resulted in damage to the surface of the micro switch contacts. This resulted in a closed circuit, which sent an uncommanded signal to the rudder solenoid valve.

3.4 The steering toggles had a durability rating of 1,000,000 cycles on a 24-volt DC circuit, with a 0.5 amp current. The durability was reduced by a factor of 10 when the current flow reached 1.2 amps.

3.5 TSF did not have a maintenance plan in place for the toggle switches that incorporated their service life expectancy under either operating condition (0.5 or 1.2 amps). The toggles were replaced as they failed.

3.6 The builder of the Emerald class vessels had not identified a shortcoming in its selection of the steering toggle through its design validation processes.

3.7 The TfNSW engineering assurance and configuration management process in place for the vessel did not include examination of the electrical supply for the steering toggle switch.

Other issues affecting safety

3.8 Following the first incident, neither TSF nor *Pemulwuy's* master reported the loss of control to authorities.

3.9 TSF did not follow its own SMS instructions to preserve data from the vessel following an incident to assist any subsequent investigation.

3.10 In the first incident, *Pemulwuy* overtook *Narrabeen* and passed Fort Denison in close proximity which left little room for contingency if a control failure occurred.

3.11 Following the first incident, TSF returned *Pemulwuy* back into service without ascertaining the underlying cause of the steering toggle switch failure.

3.12 AMSA's classification of the 2 July 2020 loss of steering incident as a less serious incident did not align with its own incident severity classifications. AMSA conducted follow-up actions commensurate with a less serious incident. As a result, the potential risks associated with a loss of control of a high capacity, high-speed passenger ferry were not considered.

PART 4 RECOMMENDATIONS

Transdev Sydney Ferries

4.1 Review its investigation procedure to incorporate identification and rectification of critical failures before vessels are returned to service.

4.2 Review its fleet wide asset maintenance plan to include preventative maintenance of vessel safety critical systems.

4.3 Configure the VDRS to capture the recording of safety critical data related to vessel control.

4.4 Review its reporting systems and processes to enable accurate and prompt reporting of safety incidents and retention of relevant data.

TfNSW

4.5 Examine the asset management framework to determine if there are opportunities for improvement in the assurance processes for procurement of domestic commercial vessels.

AMSA

4.6 Review incident reporting, classification and follow up procedures to ensure incidents are responded to consistent with their level of risk to safety.

SUBMISSIONS

The Chief Investigator forwarded a copy of the Draft Report to the Directly Involved Parties (DIPs) to provide them with the opportunity to contribute to the compilation of the Final Report by verifying the factual information, scrutinising the analysis, findings and recommendations, and to submit recommendations for amendments to the Draft Report that they believed would enhance the accuracy, logic, integrity and resilience of the Investigation Report. The following DIPs were invited to make submissions on the Draft Report:

- Transport for NSW
- Port Authority of NSW
- Harbour City Ferries (Transdev Sydney Ferries)
- AMSA.

Submissions were received from the following DIPs:

- Harbour City Ferries (Transdev Sydney Ferries)
- Transport for NSW
- AMSA
- Port Authority of NSW.

The Chief Investigator considered all representations made by DIPs and responded to the author of each of the submissions advising which of their recommended amendments would be incorporated in the Final Report, and those that would not. Where any recommended amendment was excluded, the reasons for doing so were explained.