



Australian Government

Australian Transport Safety Bureau



ATSB TRANSPORT SAFETY REPORT
Marine Occurrence Investigation No. 274
MO-2010-003
Final

Independent investigation into the grounding of the
Chinese registered bulk carrier

Shen Neng 1

on Douglas Shoal, Queensland

3 April 2010



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Figure 8 was obtained from Maritime Safety Queensland. Figure 13 and the figures in Appendix A were obtained from the Australian Maritime Safety Authority.

Abstract

At 1705 on 3 April 2010, the Chinese registered bulk carrier *Shen Neng 1* grounded on Douglas Shoal, about 50 miles north of the entrance to the port of Gladstone, Queensland. The ship's hull was seriously damaged by the grounding, with the engine room and six water ballast and fuel oil tanks being breached, resulting in a small amount of pollution.

The ATSB investigation found that the grounding occurred because the chief mate did not alter the ship's course at the designated course alteration position. His monitoring of the ship's position was ineffective and his actions were affected by fatigue.

The ATSB identified four safety issues during the investigation: there was no effective fatigue management system in place to ensure that the bridge watchkeepers were fit to stand a navigational watch after they had supervised the loading of a cargo of coal in Gladstone; there was insufficient guidance in relation to the proper use of passage plans, including electronic route plans, in the ship's safety management system; there were no visual cues to warn either the chief mate or the seaman on lookout duty, as to the underwater dangers directly ahead of the ship; and, at the time of the grounding, the protections afforded by the requirement for compulsory pilotage and active monitoring of ships by REEFVTS, were not in place in the sea area off Gladstone.

The ATSB has issued two safety recommendations to *Shen Neng 1*'s management company regarding the safety issues associated with fatigue management and passage planning and acknowledges the safety action taken by the Australian Maritime Safety Authority in relation to the extension of REEFVTS coverage to include the waters off Gladstone.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Risk level: The ATSB's assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

Safety action: the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.

EXECUTIVE SUMMARY

At 1940¹ on 24 March 2010, the Chinese registered bulk carrier *Shen Neng 1* anchored off the Queensland port of Gladstone after a voyage from Korea. The ship was in ballast and, after a period of time at anchor, was expected to berth to load a cargo of about 68,000 tonnes of coal for delivery to China.

Shortly before 0300 on 2 April, the chief mate went to the forecastle to supervise the crew weighing anchor. At 0410, after the ship was underway, a harbour pilot boarded *Shen Neng 1*. He joined the master, chief mate and helmsman on the bridge and took over the conduct of the ship for the passage to the berth. By 0720, *Shen Neng 1* was all fast alongside number one berth at the Clinton Coal wharf.

Loading started at 0820 and the chief mate actively supervised loading and deballasting operations throughout the day and into the night. Cargo operations continued without problems or delays and by midnight, deballasting was nearly complete and only a few hours of cargo loading remained.

At about 0100 on 3 April, the chief mate, satisfied with the progress of the loading, decided to rest. He slept for about 2 hours before he resumed duties to complete cargo loading. At 0540, cargo loading was completed.

At 1035, a harbour pilot boarded *Shen Neng 1* for its departure and at 1054, the ship departed the berth. At 1306, the pilot disembarked into the pilot boat and the ship's course was set on 000° (T).

After the ship had settled on this course, the second mate, with the master's permission, made an alteration to the passage plan. This alteration bypassed the next planned course alteration waypoint just off North West Island (while remaining within the designated shipping area) and joined the upcoming 075° (T) course further to the east than originally planned. The second mate drew a new course line of 020° (T) on the navigational chart in use and on the next chart to be used. At 1530, the second mate altered the ship's course to 020° (T).

Just before 1600, the chief mate came to the bridge to relieve the second mate. The second mate told the chief mate about the revision of the passage plan. The chief mate acknowledged what he had been told and the second mate, after fixing the ship's position at 1600, left the bridge. The chief mate positioned himself on the bridge where he could look out the windows and see the radar. He did not check the 1600 position or the distance to go to the next course alteration position.

At 1700, the chief mate took a position from the global positioning system (GPS) unit and when he went to plot the position on the chart, he realised the ship was entering an area of shallow water around Douglas Shoal. He immediately told the duty seaman to put the ship's helm hard over to starboard but it was too late.

At 1705, *Shen Neng 1* grounded on Douglas Shoal.

At about 1840, after reporting the grounding to the ship's managers, the master reported the grounding to the Australian Maritime Safety Authority (AMSA).

On 5 April, a salvage team boarded *Shen Neng 1* via helicopter. Over the following days, the damage was assessed and planning began for the salvage operation, which

¹ All times referred to in this report are local time, Coordinated Universal Time (UTC) + 10 hours.

included trying to remove as much fuel oil from the ship as possible. The ship's hull was seriously damaged by the grounding, with the engine room and six water ballast and fuel oil tanks being breached, resulting in about 2½ tonnes of fuel oil being lost into the sea.

At 1948 on 12 April, *Shen Neng 1* was refloated.

On 31 May, following a salvage operation which had lasted almost 2 months and included offloading 19,000 tonnes of coal from the ship, *Shen Neng 1* was taken in tow bound for China.

The ATSB investigation found that the grounding occurred because the chief mate did not alter the ship's course at the designated course alteration position. His monitoring of the ship's position was ineffective and his actions were affected by fatigue.

The investigation also found that the passage plan the ship was following before the grounding had been amended after sailing but the amendments were not entered into the GPS route plan. Consequently, the defences the GPS unit provided had been rendered ineffective for the amended part of the passage. In addition, the chief and second mates did not follow company and industry guidelines when they completed the watch handover.

The ATSB report identifies the following four safety issues:

- There was no effective fatigue management system in place on board *Shen Neng 1* to ensure that the bridge watchkeeper was fit to stand a navigational watch after the loading in Gladstone.
- The ship's safety management system did not contain procedures or guidance on the proper use of GPS route plans and their relationship to the ship's passage plans.
- In the 30 minutes leading up to the grounding, there were no visual cues to warn either the chief mate or the seaman on lookout duty, as to the underwater navigation hazards directly ahead of the ship.
- At the time of the grounding, the protections afforded by a requirement for compulsory pilotage or active monitoring of ships by REEFVTS were not in place in the sea area off Gladstone.

The ATSB has issued two safety recommendations to *Shen Neng 1*'s management company regarding the safety issues associated with fatigue management and passage planning and acknowledges the safety action taken by the Australian Maritime Safety Authority in relation to the extension of REEFVTS coverage to include the waters off Gladstone.

1 FACTUAL INFORMATION

1.1 *Shen Neng 1*

Shen Neng 1 is a conventional, gearless panamax² bulk carrier (Figure 1). The ship was built in 1993 by Sanoyas Hishino Meisho Corporation, Kurushiki, Japan. It has an overall length of 225.0 m, a breadth of 32.3 m and a depth of 18.3 m. The ship has a deadweight of 70,181 tonnes at its summer draught of 13.291 m.

Figure 1: *Shen Neng 1* aground on Douglas Shoal



Shen Neng 1 has seven cargo holds located forward of the accommodation superstructure. The ship's double bottom extends under the cargo holds and is divided into nine water ballast and four fuel oil tanks. The fuel oil tanks, one under each of the four after cargo holds, are centre tanks and have water ballast tanks on either side. The ship's remaining bunker fuel oil and diesel oil tanks are located in the engine room.

Propulsive power is provided by a Sulzer 6RTA62 two-stroke, single acting, direct reversing, diesel engine that develops 8,827 kW at 97 rpm. The main engine drives a single, fixed-pitch propeller. The main engine is normally operated at 83 rpm which gives the ship a service speed of about 12 knots³.

At the time of the incident, the ship was owned by Shenzhen Energy Transport, and managed by Tosco Keymax International Ship Management Company, both of China. It was registered in China and classed with the China Classification Society (CCS).

² A ship that is limited in size to the dimensions of the Panama Canal.

³ One knot, or one nautical mile per hour equals 1.852 kilometres per hour.

The ship's navigation bridge was equipped with navigational equipment consistent with SOLAS⁴ requirements. This included two global positioning system (GPS) units (a Raytheon NAV398 and a Furuno GP-80), a Sailor KDU1905 automatic identification system (AIS) unit and two X-band radars.

The ship's global maritime distress and safety system (GMDSS) station was situated in the starboard aft part of the bridge and included an Inmarsat-C satellite communications terminal. The ship was not equipped with any form of electronic charting system.

At the time of the incident, *Shen Neng 1* had a crew of 23 Chinese nationals who held qualifications for their positions in accordance with international requirements. The deck officers comprised the master and three mates. While at sea, at anchor and in port, the mates maintained a traditional watchkeeping routine of 4 hours on and 8 hours off. The third mate kept the 8 to 12 watch, the second mate kept the 12 to 4 watch and the chief mate kept the 4 to 8 watch. In port, the chief mate worked additional hours as required for cargo operations.

The master had 24 years of seagoing experience and had sailed on general cargo ships and bulk carriers, including many panamax ships. He obtained his Chinese master's qualifications in 1992, and was promoted to master in 2003. He joined *Shen Neng 1* for his first assignment with the ship's managers about 6 months before the grounding. While he had visited Australian ports in the past, this was his first visit to Gladstone.

The chief mate had 20 years of seagoing experience, the last 11 years as a mate in charge of navigation watches. In 2007, he obtained his Chinese qualifications as a chief mate and was promoted to that rank. In 2008, he began working for *Shen Neng 1*'s managers. He joined *Shen Neng 1* in Korea about 1 month before the grounding. Like the ship's master, this was his first visit to Gladstone.

The second mate had been at sea for 12 years, the last 10 with *Shen Neng 1*'s managers. He had over 5 years experience as a mate in charge of navigation watches and held Chinese second mate's qualifications. *Shen Neng 1* was his second ship as second mate and he had been on board for about 4 months.

1.2 The Great Barrier Reef

The Great Barrier Reef (GBR) is a marine park and world heritage area. In 1990, the GBR was also declared a Particularly Sensitive Sea Area (PSSA) by the International Maritime Organization (IMO). Under the World Heritage Convention, and in accordance with its standing as a PSSA, Australia has an international obligation to protect the reef and its wildlife.

Apart from the reef itself and the wildlife it supports, the GBR region sustains a variety of commercial and recreational activities, including fishing and tourism. These activities are worth in excess of \$5 billion per year to the Australian economy⁵.

⁴ The International Convention for the Safety of Life at Sea, 1974, as amended.

⁵ Australian Maritime Safety Authority. *Improving safe navigation in the Great Barrier Reef*, April 2010.

Eleven ports operate within the confines of the GBR Marine Park and together they account for about \$11 billion of Australia's export trade⁶. These ports also service about 1 million people who live in northern Queensland. Consequently, arrangements have been put in place to accommodate shipping within the GBR area, while protecting the environmental importance of the reef area and its wildlife.

1.2.1 Existing measures to protect the GBR

Over the past 20 years, a number of measures have been implemented to protect the environmental sensitivity of the GBR Marine Park, including the declaration of the region as a PSSA by the IMO in 1990. This allowed Australia to introduce a number of protective measures in the region.

In 1991, compulsory pilotage was introduced for ships transiting the GBR between Cairns and Cape York. This was followed in 1997 by the introduction of an IMO adopted ship reporting system, requiring ships to report their positions on a regular basis.

In 2004, a coastal vessel traffic service⁷ (VTS) was introduced. This service provided near real-time monitoring of ships in the GBR in the area north of 22°S and provided masters of ships with information on potential traffic conflicts and other navigation information. Also in 2004, a system of zoning was introduced to allow ships to transit the reef in designated areas. This included general use zones and designated shipping areas⁸ (DSAs).

To complement all the above measures, an extensive aids-to-navigation network, including lights, buoys and satellite systems, has been developed throughout the GBR.

1.2.2 Compulsory pilotage

In a number of areas of the GBR Marine Park, relatively confined and navigationally complex waters saw the introduction of compulsory pilotage. The introduction was seen as a way to reduce the risk of pollution within the GBR caused by incidents involving ships transiting those areas.

Under the compulsory pilotage requirements, specified vessels must carry a licensed pilot when transiting through the Inner Route of the GBR, specifically between Cape York (10° 41'S) and the vicinity of Cairns Roads, north of Cairns (16° 40'S), when passing through Hydrographer's Passage or within the Whitsunday Islands.

The requirement applies to all vessels of 70 m or more in length, and to all loaded oil and chemical tankers or liquefied gas carriers of any length. Cruise ships in the Whitsunday Islands must also carry a licensed pilot.

⁶ Australian Maritime Safety Authority. *Improving safe navigation in the Great Barrier Reef*, April 2010.

⁷ IMO Resolution A.857 (20) defines a VTS as a service implemented by a Competent Authority, designed to improve the safety of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and respond to traffic situations in the VTS area.

⁸ In general, commercial ships of 50 m or more in length and all types of specialised carriers and tankers, regardless of length, must navigate within DSA limits.

1.2.3 The Great Barrier Reef and Torres Strait Vessel Traffic Service (REEFVTS)

The declared objectives of REEFVTS are to enhance navigational safety in its designated area by interacting with shipping, to minimise the risk of a ship related incident, environmental damage and pollution and to provide the ability for a quicker response to an incident.

The major components of REEFVTS are a ship reporting system (REEFREP⁹), and monitoring and surveillance systems, including AIS, radar, automated position reporting via Inmarsat-C polling and VHF radio reports. These systems and various databases are integrated into a traffic information module (TIM). The TIM display uses electronic navigational charts and ship position and track information is displayed using data from AIS, radar or Inmarsat-C polling. This makes real or near real time monitoring possible and automated alarms are used to monitor ships in the large area covered by REEFVTS (Figure 2).

At the time of the incident, the service's 24 hour operational centre, REEFCENTRE, was located at Hay Point near Mackay. To enhance coordination and communication, the centre was electronically linked to AMSA's Rescue Coordination Centre (RCC) in Canberra.

The services provided by REEFVTS to shipping include navigational assistance (information to assist shipboard decision making), ship traffic information (STI) and maritime safety information (MSI). The STI consists of TIM-generated ship encounter predictions which include ship's names and encounter times for the next 6 hours and any changes to earlier predictions. The MSI includes navigational warnings and information. Ships receive STI and MSI when entering the area and then at least every 5 hours, normally via Inmarsat-C.

Navigational assistance is usually provided via VHF radio. Ships are required to keep a listening watch on the appropriate REEFVTS VHF channel and channel 16. Reports when a ship enters or exits the area and when a pilot boards or disembarks a ship are also made via VHF radio.

To effectively monitor shipping in the REEFVTS area, and to facilitate the provision of navigational assistance to ships, the TIM is set up to generate automatic alarms. The alarms are intended to provide the duty officer with an early warning of a ship standing into shallow water, deviating from its normal route or approaching a critical course alteration point so that a hazardous situation can be avoided. When a ship breaches limits defined in the TIM, the corresponding alarm (shallow water alert, exiting corridor¹⁰ alarm or critical turn alarm) is triggered.

At the time of the incident, REEFVTS provided VTS coverage of the Torres Strait and the northern part of the GBR. The southern limit of the REEFVTS area was at latitude 22°S, near High Peak Island, about 120 miles north of Gladstone (Figure 2).

⁹ The Great Barrier Reef and Torres Strait Ship Reporting System (REEFREP) is a mandatory ship reporting system applicable to all ships 50 m or more in length, all types and sizes of tankers and other ships that present a higher risk, which are defined in the system's regulations.

¹⁰ Electronic corridors defined in the TIM are described as 'intelligent' lines and areas to represent key navigation areas used by transiting ships in the VTS area.

Figure 2: Area covered by REEFVTS at the time of the incident



1.2.4 Shipping zones within the GBR

To facilitate trade within the GBR Marine Park, a DSA was established through the Inner Route of the GBR, recognised passages and all port approaches in the GBR Marine Park. The DSA accommodates vessels using accepted or normally used routes.¹¹

According to the Australian Seafarers Handbook¹², published by the Australian Hydrographic Service:

Ships may transit the marine park through the General Use Zone or the Designated Shipping Areas. Shipping Areas may be used or entered without permission for the navigation of a ship, subject to any requirements for a compulsory pilot, or to stow or secure fishing equipment. The Designated Shipping Areas in the Great

¹¹ Admiralty Sailing Directions. Australia Pilot Vol III (NP 15). Tenth edition 2005, page 9.

¹² Second edition, 2009, page 85.

Barrier Reef Marine Park Zoning Plan reflect vessel usage patterns in the inner and outer shipping routes, existing recommended tracks and proposed new routes to allow for growth in shipping.

1.3 Gladstone and approaches

The port of Gladstone is located on the Central Queensland coast near latitude 24°S, about 250 miles¹³ north of Brisbane. About 20 per cent of Australia's coal exports pass through Gladstone, making it the country's third largest coal port. In the financial year ending 30 June 2009, more than 56 million tonnes of coal was exported via Gladstone. Coal exports comprised over 70 per cent of the total cargo handled at the port. The port's other main cargoes were bauxite, alumina and cement. Of the 1,396 cargo carrying ships that visited Gladstone during this period, 665 loaded coal bound for ports in Asia.

The Gladstone VTS manages shipping movements within the port's pilotage area. The offshore limit of the pilotage area extends about 2 miles east of the pilot boarding ground and includes anchorages at the port's entrance. Departing ships make their last report to VTS when disembarking the harbour pilot and VTS monitors them until they have cleared the pilotage area limit.

1.3.1 Shipping routes from Gladstone through the GBR

The sea area off Gladstone is south of 22°S. Therefore, at the time of the incident, it fell outside coverage by REEFVTS and coastal pilotage requirements. The sea areas are relatively open and not as navigationally complex as the northern section of the GBR and ships navigating in the permitted zones and DSAs in this area do so in accordance with the usual practices of seamanship and vigilance.

Data provided by AMSA indicate that each year, over 1,500 vessels make safe passages through the waters off Gladstone and the Capricorn and Bunker Groups. These ships make the passage without reporting their positions to a shore authority, without being actively monitored by a coastal VTS and without a coastal pilot on board.

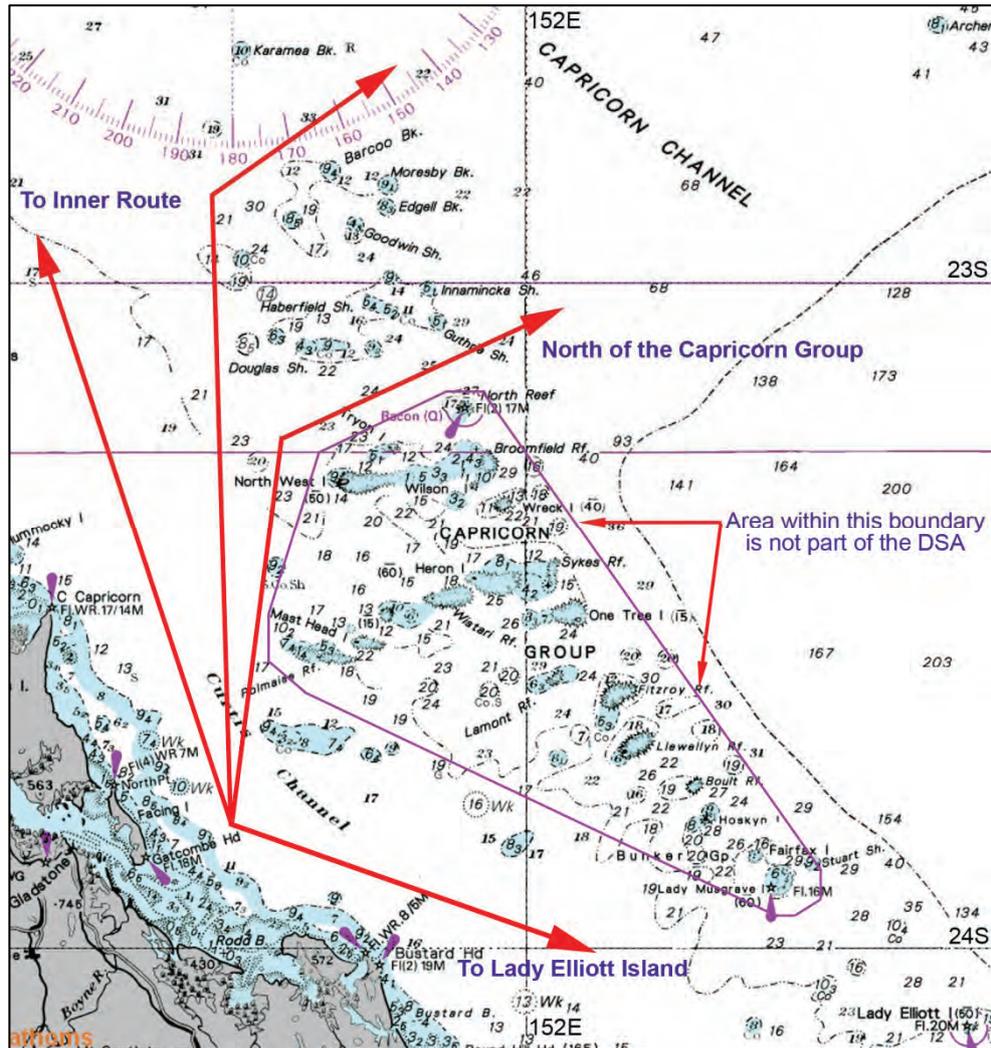
Ships departing Gladstone have a choice of routes which will take them out of the GBR Marine Park (Figure 3). Which route a ship uses is principally determined by its destination and draught.

Ships intending to transit the Torres Strait, where the maximum draught is 12.2 m, usually follow the Queensland coast northwards along the Inner Route of the GBR.

Many other ships departing Gladstone exit the GBR near the port and then set a course towards their destinations. The GBR area off Gladstone is not a compulsory pilotage area and can be safely navigated using the general use zone and DSAs between the islands, reefs and shoals. DSAs are clearly marked on the appropriate scale navigational charts.

¹³ A nautical mile of 1852 m.

Figure 3: Route options for ships departing Gladstone



One of the common shipping routes is past Lady Elliott Island, east-southeast of Gladstone. Lady Elliott Island and other smaller islands in its vicinity are fitted with navigation aids, including lights, to assist ships to safely navigate in the area.

Another navigable passage to the north-northeast of Gladstone is between the Capricorn Group and Guthrie and Douglas Shoals (Figure 3). A powerful navigation light, with a racon¹⁴, is located on North Reef to assist in the safe navigation of ships through this passage. This passage is within the DSA and it is estimated that about half of the ships entering or exiting the GBR area off Gladstone use this passage, with the other half entering or exiting via Lady Elliott Island (Appendix A).

¹⁴ A radar beacon which transmits a morse code signal when it receives a radar signal from a ship and thus identifies the navigation aid on the ship's radar display.

1.4 The incident

At 1940¹⁵ on 24 March 2010, *Shen Neng 1* anchored in the anchorage off the port of Gladstone after a 13 day voyage from Yosu, Korea. The ship was in ballast and was expected to berth after a week to load a cargo of about 68,000 tonnes of coal for delivery to China.

While at anchor, the ship's crew carried out their routine duties and normal maintenance work. The three mates kept their usual watches at anchor.

From 30 March through to 1 April, the chief mate spent about 3 hours after each evening watch checking his cargo and stability calculations and comparing them to the cargo loading computer calculations.

At about 0200 on 2 April, Gladstone VTS informed *Shen Neng 1*'s master that a harbour pilot would board the ship at about 0400. Preparations were made to get under way and shortly before 0300 the chief mate went to the forecastle to supervise the crew weighing anchor.

By 0320, the anchor was aweigh. The master turned the ship and navigated it towards the pilot boarding ground.

At about 0330, the chief mate came back to the accommodation and began to get ready for his watch. At about 0400, he relieved the second mate on the bridge.

At 0410, a pilot boarded *Shen Neng 1* via a pilot boat. He joined the master, chief mate and helmsman on the bridge and, after an exchange of information, took over the conduct of the ship for the passage to its berth.

At about 0600, the crew went forward and aft to make the tugs fast. The third mate relieved the chief mate on the bridge, who then went to the forecastle. The second mate went to his usual station aft. By 0615, the tugs were made fast and the ship was turned and manoeuvred towards its berth.

By 0720, *Shen Neng 1* was all fast, starboard side alongside number one berth at the Clinton Coal wharf. Immediately afterwards, the chief mate came back from the forecastle to the ship's office and prepared for cargo loading.

During his meeting with the coal terminal representative, the chief mate was told to expect an average loading rate of about 5,200 tonnes per hour¹⁶. This was to be his first loading of the ship and he was not familiar with the ship's ballast system. As a result, he was concerned that if the de-ballasting did not keep up with cargo loading, there would be delays.

Loading started at 0820 and the chief mate actively supervised loading and deballasting operations throughout the day and into the night. While the other two mates supervised cargo operations out on deck, the chief mate remained in the ship's cargo office/control room, taking meal breaks when he could. Loading was continuous and he remained busy, dealing with the crew and shore personnel.

¹⁵ All times referred to in this report are local time, Coordinated Universal Time (UTC) + 10 hours.

¹⁶ The nominal loading rate is 6,000 t per hour for each loader at the terminal (Port of Gladstone, Port information handbook 2008).

The cargo loading and deballasting operations continued without problems or delays. By midnight, deballasting was nearly complete and only a few hours of cargo loading remained.

At about 0100 on 3 April, the chief mate, satisfied with the progress of the loading, left the second mate in charge and went to his cabin. The chief mate slept until 0300, when he was called after the cargo surveyor had boarded the ship. At 0540, *Shen Neng 1* completed loading 68,052 tonnes of coal. The ship's draughts were 13.29 m forward and 13.38 m aft. For its intended 4,500 mile voyage to China, the ship had 978 tonnes of bunker fuel oil and 154 tonnes of diesel oil on board.

At 0610, after completing the draught survey, the cargo surveyor and the chief mate attended to the necessary cargo calculations and associated paperwork. By about 0730, the surveyor had passed on the final figures to the terminal and other parties ashore. However, the chief mate continued checking the cargo figures and ship stability calculations and attending to the cargo stowage plan and other shipboard forms. At 0900, he went for breakfast, returning about 30 minutes later to complete the paperwork.

At 1035, a harbour pilot boarded *Shen Neng 1* for its departure. The master and third mate were on the bridge and the chief and second mates were at their usual stations forward and aft. By 1043, the tugs had been made fast and at 1054, the ship departed the berth.

Shortly after 1100, with the ship in the shipping channel and clear of the berth, the tugs were let go. At about 1115, the mates forward and aft were stood down. The shipwright remained standing by the anchors in case they were needed during the pilotage.

By 1200, the second mate had relieved the third mate on the bridge. *Shen Neng 1* was making good a speed of about 9 knots and had completed more than half the pilotage passage. The helmsman was steering to the pilot's orders and the master was monitoring the ship's progress.

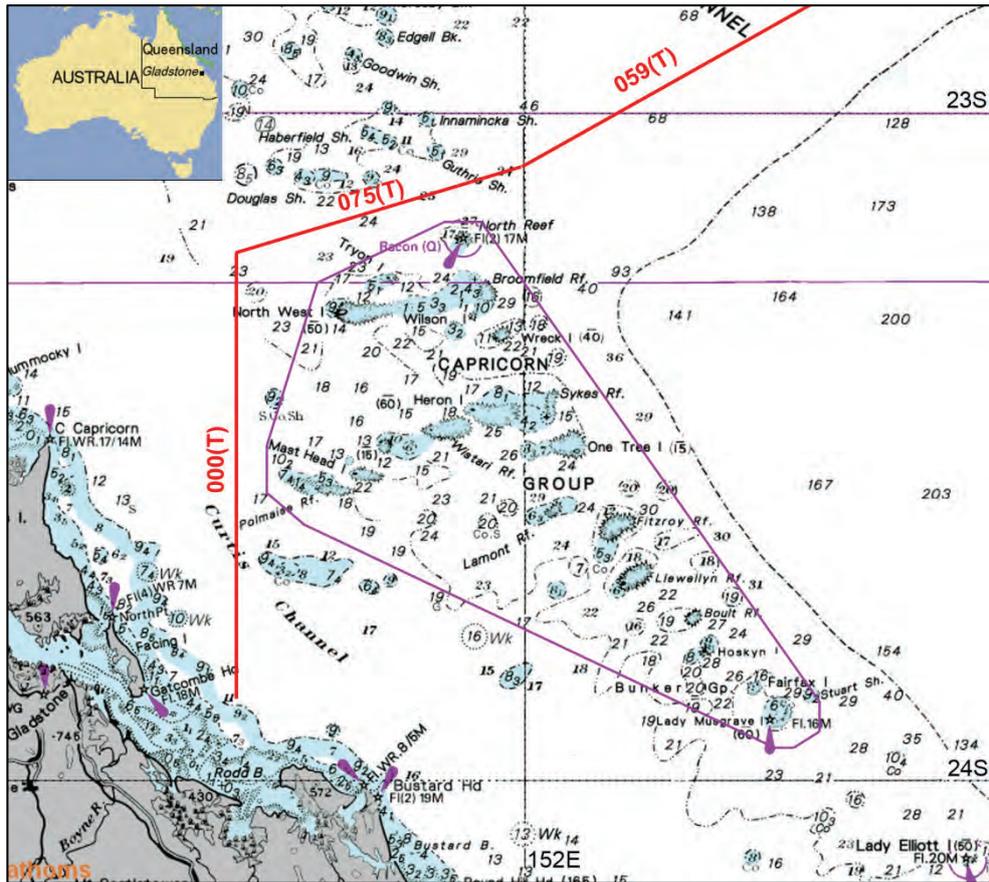
During the pilotage, the pilot noted from the chart that the master intended to steam north from the pilot boarding ground and exit the GBR area via the passage to the north of North West Island and North Reef (Figure 4).

At about 1220, the chief mate finished lunch and went to his cabin to smoke a cigarette. He showered, had another cigarette and relaxed. After that, he lay on his bunk and set his alarm clock to wake him at 1530 for his watch. Sometime later, he fell asleep.

At 1306, with *Shen Neng 1* on a course to keep clear of an inbound ship, the pilot disembarked into the pilot boat.

At 1330, *Shen Neng 1*'s position was fixed using the GPS and plotted on the chart. The position indicated that the ship was on the intended course line and, having passed the other ship, its course was altered to steer 000° (T). The master then requested full sea speed and *Shen Neng 1* commenced its voyage to China. The weather was good with a partly cloudy sky, clear visibility, a south-easterly breeze at about 15 knots and slight seas.

Figure 4: Shen Neng 1's intended passage from Gladstone

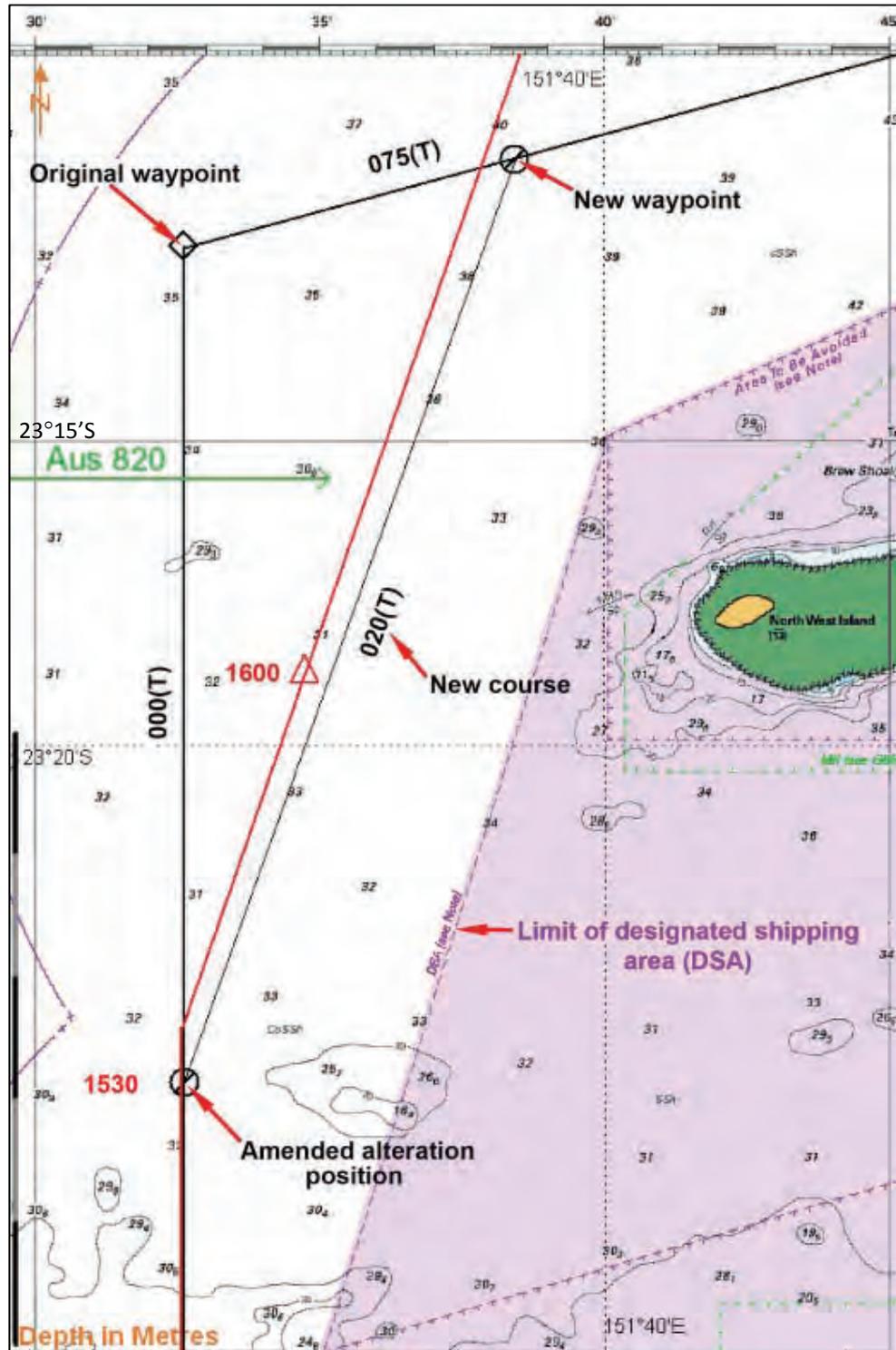


Shortly afterwards, the auto-pilot was engaged and the duty seaman posted as a lookout. The second mate asked the master if he could adjust the planned route to slightly reduce the distance of the voyage and indicated the proposed new track on the chart. This new course would amend the planned passage just off North West Island and bypass the next course alteration waypoint (from 000° (T) to 075° (T)). The new course would rejoin the 075° (T) track further to the east than planned, thereby reducing the distance by nearly 2 miles (Figure 5).

The new track of 020° (T) would be parallel to, and about 3 miles from, the DSA limit off North West Island. The master agreed and gave permission to change the passage plan.

The second mate laid the new course line of 020° (T) on the chart in use and on the next one, charts Aus 819 and Aus 820 respectively. The original course line of 000° (T) marked on both charts was not erased. A 'change of chart' line with the notation 'Aus 820' which had been marked on chart Aus 819 across the 000° (T) course line also remained unaltered.

Figure 5: Annotated section of navigational chart Aus 819 showing the original and amended route, and the ship's position fixes (the red line indicates the ship's actual track)



Before the ship departed Gladstone, the original waypoints in the passage plan had been set in the Furuno GPS unit mounted on the chart table. The unit could indicate the distance that *Shen Neng 1* was away from the planned track (cross track error) and the associated cross track error alarm was set for 3 cables¹⁷. The unit also indicated the bearing and distance to the next waypoint and the waypoint arrival alarm was set to activate at a distance of 2 cables. The operational radar automatically displayed the bearing of the next waypoint which could be used to assist in determining a course to steer to that waypoint.

When amending the passage plan, the second mate wrote the coordinates of the amended waypoints next to them on the charts but he did not enter these coordinates in the GPS unit.

By 1400, *Shen Neng 1* was making good a speed of about 12 knots and its main engine had reached 83 rpm, full sea speed. The 1400 GPS fix showed the ship was on the planned track. The master handed over the conduct of the ship to the second mate and left the bridge. The duty seaman remained on the bridge as a lookout.

At 1500, the next GPS fix indicated that the ship was still on the planned track.

At 1530, *Shen Neng 1* was at the amended course alteration position (Figure 5). The second mate marked the time on the chart and altered course to steer 020° (T). Soon afterwards, the GPS cross track error alarm sounded, indicating that the ship had moved 3 cables off the 000° (T) course line. The second mate acknowledged the alarm. Although the ship was now steering the new 020° (T) course, the GPS unit and radar continued to indicate waypoint and cross track error information relative to the original track.

At 1530, the chief mate's alarm clock woke him. He had slept for about 30 minutes. A couple of minutes later, he got up and began getting ready to go on watch.

At 1550, shortly after the second mate called him for his watch, the chief mate arrived on the bridge. He checked the log book and chart on which the second mate showed him the new 020° (T) course and explained the changes to the passage plan. The second mate showed the chief mate the next waypoint and pointed out that the amended waypoints had not been entered in the GPS unit. The chief mate acknowledged the changes.

At 1600, the second mate fixed *Shen Neng 1*'s position by GPS, put it on the chart and handed the watch over to the chief mate. He then left the bridge.

The chief mate noted North West Island, and the other dangers in the area to be avoided to starboard, on chart Aus 819. He looked at the chart and estimated that the ship would be at the next waypoint, for the 075° (T) course alteration, at about 1700.

The chief mate decided that he would fix the ship's position at 1630 and consequently, chart Aus 819 remained on the chart table. Feeling tired, he positioned himself on the starboard side of the wheelhouse, where he had a clear view out of the bridge windows and of the ARPA radar display.

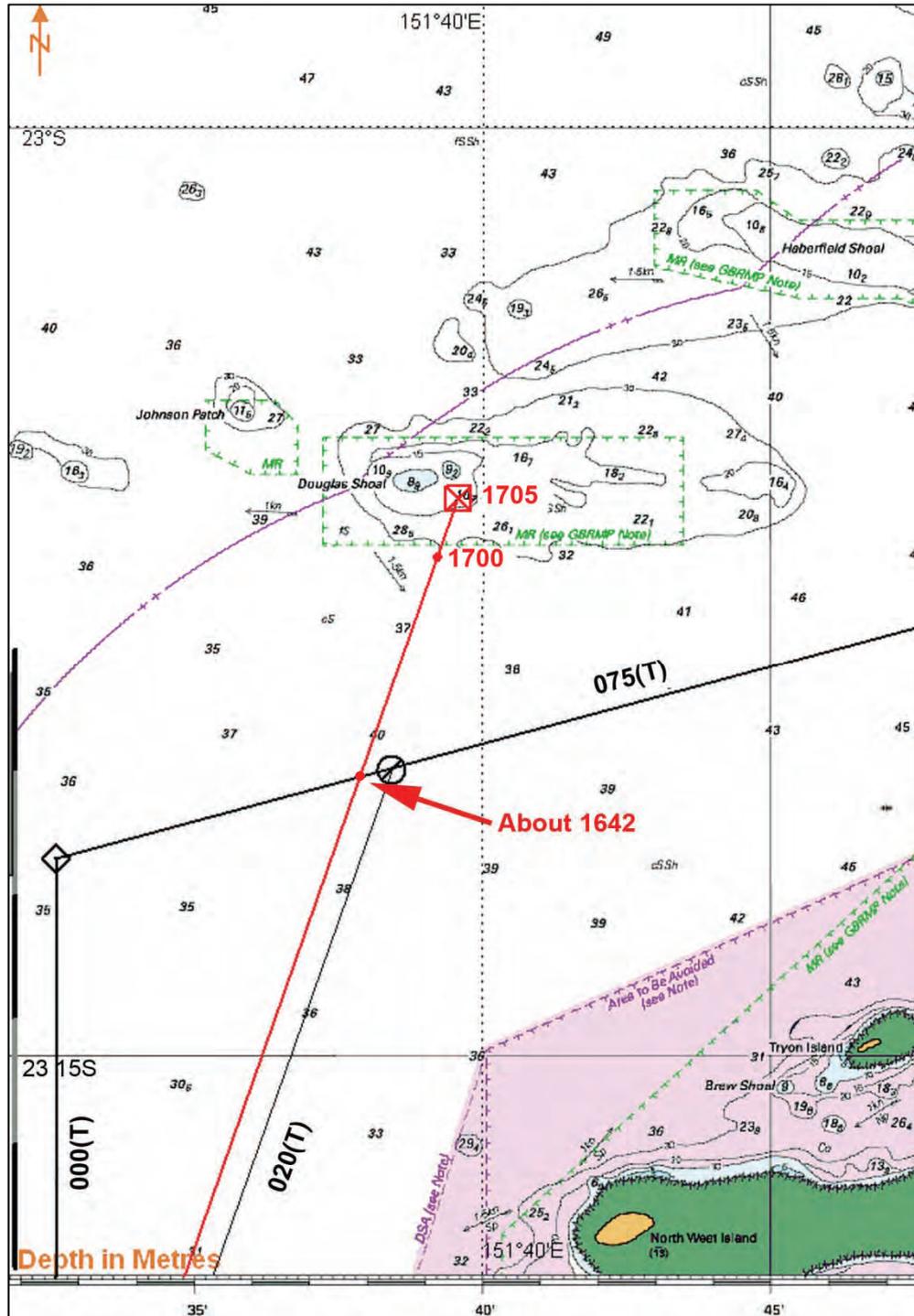
The weather was still good, the wind had freshened to about 20 knots from the east-southeast with moderate seas on a low swell. The duty seaman stood in the forward

¹⁷ One cable equals one tenth of a nautical mile or 185.2 m.

part of the bridge and kept a lookout. There was no traffic in the vicinity and there was little communication between the chief mate and the seaman.

At about 1630, the chief engineer came to the bridge, saw the main engine was at 83 rpm and asked for the ship's speed. The chief mate, still near the starboard radar, advised that the speed was about 12 knots. At about 1635, the chief engineer left the bridge. The interruption had prevented the chief mate fixing the ship's position at 1630 so he decided that he would fix the ship's position at 1700.

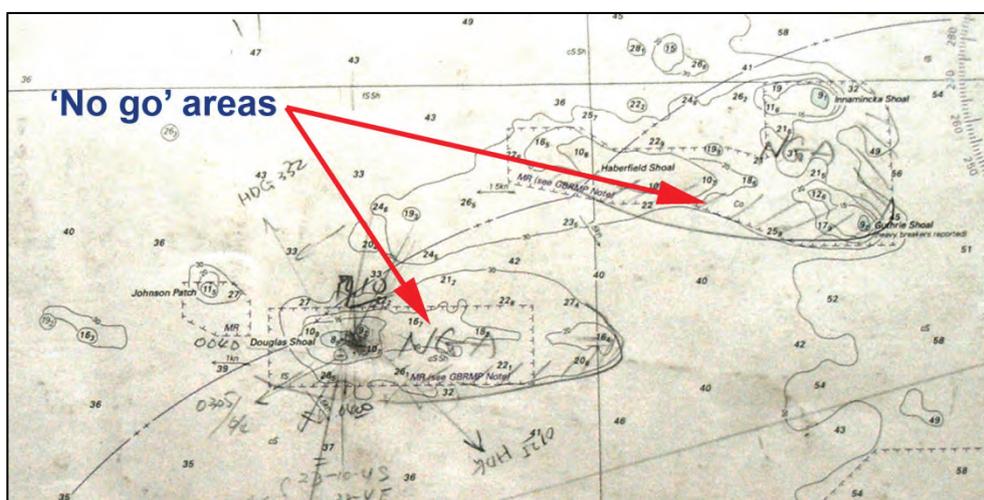
Figure 6: Annotated section of navigational chart Aus 820 showing the original and amended route, and the ship's grounding position



At about 1642, *Shen Neng 1* crossed the 075° (T) course line in the vicinity of the amended waypoint (Figure 6). On the ship's heading of 020° (T), Douglas Shoal was less than 5 miles ahead. The shoal, with a least depth of 8.9 m, gave no indication of its presence in the prevailing sea conditions.

At about 1700, the chief mate recorded the GPS coordinates 23°07.0'S 151°39.2'E in the GPS log book. This position was not on chart Aus 819 and he took out chart Aus 820 from the chart table drawer so that he could plot the position. As he placed the chart on the chart table, he noticed the ship's speed had decreased to about 8 knots. He then saw the 'no go area' marked on the chart near the Marine Park boundary around Douglas Shoal and realised the ship was entering the boundary area and closing on the shoal (Figure 7).

Figure 7: *Shen Neng 1*'s navigational chart Aus 820 showing the 'no go areas' marked around Douglas and Guthrie/Haberfield Shoals



He immediately ordered the lookout to engage hand steering and quickly alter course to starboard. However, just as hand steering mode was engaged, the chief mate saw the ship's speed rapidly decrease and the ship began to shudder. The starboard helm had no effect and soon the ship's speed was close to zero.

By 1705, *Shen Neng 1* had come to a shuddering stop and grounded on a heading of 020° (T). The GPS unit indicated the position 23° 06.0'S 151° 39.6'E, close to a charted depth of 10.7 m on Douglas Shoal where the seabed is composed of coarse sand, shells and coral. It was almost low tide at Douglas Shoal.

In his cabin, the master was attending to paperwork when he felt the ship shudder. He initially thought the ship's course was being altered. However, a minute or so later, the chief mate telephoned, asking him to come to the bridge. The master hurried to the bridge where the chief mate told him that the ship may have grounded. The master noticed that the ship's speed was zero and asked for the ship's position to be fixed. The GPS fix plotted by the chief mate confirmed that *Shen Neng 1* was aground.

Shortly afterwards, alarmed by the ship's unusual movement, the chief engineer and the second mate arrived on the bridge. The master asked the chief engineer to stop the main engine and then sent the chief mate forward to let go an anchor. He also ordered all tanks sounded and water depths around the ship checked.

At 1730, the starboard anchor was let go and 2 shackles¹⁸ of anchor cable put in the water. Tank soundings revealed that *Shen Neng I*'s hull had been breached. Number three port double bottom water ballast tank was flooded and there was water ingress into other water ballast tanks on the port side. Depth soundings around the ship confirmed that it was hard aground. A minimum depth of 11 m was measured on the ship's port side near its mid-length and a minimum depth of 12 m was measured on its starboard side.

The master informed the ship's managers and subsequently updated them as the situation developed.

At about 1840, the master reported the grounding to the Australian Maritime Safety Authority (AMSA). By about 1900, AMSA had issued a notice to shipping and made necessary notifications to various parties, including the Gladstone regional harbour master (RHM). The RHM started making arrangements for a response by establishing an incident control centre at the Gladstone offices of Maritime Safety Queensland (MSQ).

Over the next few hours, the RHM made the necessary arrangements for the supply of aircraft, pollution response equipment and personnel. By 2330, a suitable night operation helicopter had left Gladstone for *Shen Neng I*'s location on Douglas Shoal with an AMSA casualty coordinator on board.

At 0024 on 4 April, the casualty coordinator boarded the ship. The helicopter pilot could not confirm sighting any oil pollution near the ship and returned to Gladstone. Later, the casualty coordinator confirmed some pollution from a breached bunker fuel oil tank. Oil had been forced out of fuel oil tank air vents on deck and it was estimated that about 2½ tonnes of bunker oil was lost overboard. Oil and water had also entered the engine room and the main engine was disabled.

During the night, *Shen Neng I*'s heading changed as the ship moved with the higher tide. However, it remained aground. The casualty coordinator offered the master and crew advice relating to measures to minimise damage and pollution. This advice was taken.

After about 0545, fixed-wing aircraft were deployed to spray oil spill dispersant in the area around the ship. A water police vessel and an MSQ survey vessel, despatched during the night, had arrived at the ship's location to monitor the situation and assist the incident response. Arrangements were being made for a tug from Gladstone and another from Brisbane to proceed to the ship's location.

On 5 April, a team from Svitzer Salvage Australasia, who had been appointed as salvors, boarded *Shen Neng I* via helicopter. Over the following days, the salvage crew assessed the damage and began planning for the salvage operation, which included trying to remove as much bunker fuel from the ship as possible.

At 1948 on 12 April, *Shen Neng I* was refloated. The ship was towed to a location north of Great Keppel Island, where it was anchored to allow the salvors to further assess the damage. At 0655 on 21 April, the ship was taken in tow bound for the anchorage off Gladstone. The intention was to eventually tow the ship into Gladstone to offload some of its cargo.

¹⁸ One shackle equals 90 feet or 27.43 m.

Shen Neng 1 arrived at the anchorage on the morning of 22 April. However, unsatisfactory weather conditions prevented the ship from entering Gladstone harbour. As a result, a direction¹⁹ was issued by AMSA on 29 April, identifying sheltered waters in Hervey Bay, to the southeast of Gladstone, as a suitable location to conduct the offloading operation.

Between 29 April and 1 May, a more thorough underwater inspection of the damage was carried out while the ship was at anchor off Gladstone. The inspection revealed that the ship's bottom had suffered extensive plate damage. This damage comprised plate indentation, push-up, buckling and cracking. The rudder was slightly damaged but the propeller was not.

Between 9 and 12 May, *Shen Neng 1* was towed to Hervey Bay. Over the next 7 days, 19,000 tonnes of coal was offloaded into smaller ships (Figure 8). The salvors determined that, with the cargo removed, the ship could be safely towed to an overseas port for repairs.

On 24 May, *Shen Neng 1* arrived back at an anchorage off Gladstone to await the arrival of an ocean going tug. On 31 May, following a salvage operation that lasted almost 2 months, *Shen Neng 1* was taken in tow by the tug *De Da* for a voyage to China.

Figure 8: Coal offloading operations being conducted in Hervey Bay



¹⁹ An intervention instruction issued by AMSA, in accordance with the *Powers of Intervention Act*, identifying a place of refuge.

2.1 Evidence

On 6 April 2010, investigators from the Australian Transport Safety Bureau (ATSB) boarded *Shen Neng 1* while it was aground on Douglas Shoal. They interviewed the master, the chief mate, the second mate, the chief engineer and the seaman on watch at the time of the incident and each provided their account of the incident. The investigators took copies of relevant records and documents, including the navigational chart used, deck log book, bell book, position log, passage plans, work and rest hour records, ship's procedures and various other documents.

On 9 April, investigators again boarded the ship and held further interviews with the ship's master and chief mate.

The data card from the ship's simplified voyage data recorder (S-VDR) was also temporarily retained. However, the card did not contain any incident-related data as the crew did not back-up the system at the time of the grounding, or in the hours immediately following it, despite having been advised to do so by the ATSB.

The investigators found the ship's gyrocompass, the global positioning system (GPS) units and the JRC radar to be in working order. The course recorder was not running on 3 April because it had broken down, and was not repaired when the ship arrived in Gladstone.

While in Gladstone, the ATSB investigators attended the incident control centre at the offices of Maritime Safety Queensland (MSQ) on a number of occasions. As the lead agency, MSQ coordinated the incident response through its regional harbour master (RHM) and staff working with a number of agencies. The acting RHM at the time of the grounding was interviewed and he provided his account of the initial response and establishing the incident control centre.

During the course of the investigation, further information was obtained from MSQ, the Australian Maritime Safety Authority (AMSA) and the Australian Hydrographic Service.

2.2 The grounding

Shen Neng 1 grounded on Douglas Shoal about 20 minutes after there should have been a change of course that would have taken the ship safely through the centre of a passage between the Capricorn Group and the Douglas and Guthrie Shoals in accordance with its passage plan.

After the ship departed Gladstone, the second mate, with the master's permission, made a slight change to the ship's passage plan to the northwest of the Capricorn Group. The intention of this change was to reduce the voyage by about 2 miles. While the second mate changed the courses on the paper charts, no change was made to the GPS route plan. As a result, the defences provided by the GPS unit (cross track error and waypoint approach alarms) were inadvertently rendered ineffective for the altered section of the passage plan.

Shen Neng 1's loading in Gladstone was the chief mate's first time in charge of loading the ship. He was unfamiliar with the operation and reliability of the ship's ballast system and, to ensure that loading was not delayed by any problem with deballasting, chose to remain on duty for the majority of the time the ship was berthed. Consequently, he had only had about 2½ hours sleep in the preceding 38½ hours before the grounding.

Despite the fact that he had not had adequate rest to ensure that he was fit to be in charge of a navigational watch, he was permitted to relieve the second mate at 1600 on 3 April.

From when he took over the watch at 1600 to when the ship ran aground, the chief mate made a succession of errors which were probably brought about by his lack of sleep. These errors resulted in the chief mate not altering the ship's course when he was required to and the ship ran aground.

At the time of the grounding, because the sea area off Gladstone is relatively open water and less navigationally complex for competent mariners, ships transiting the area were not required to carry a coastal pilot nor were they subjected to the active monitoring capability of Great Barrier Reef and Torres Strait Vessel Traffic Service (REEFVTS). Consequently, there was no oversight of the ship's progress after the Gladstone pilot disembarked the ship.

2.3 The chief mate's work schedule

Technology has seen the loading rates of shiploaders at Australian export bulk terminals increase markedly over recent years. At the time of the incident, the loading rate at the Clinton Coal terminal in Gladstone was about 6,000 tonnes per hour. However, at other terminals, the rate was in excess of 10,000 tonnes per hour.

In submission, MSQ stated that:

Australia is rapidly expanding its export capacity for bulk resources such as coal, iron ore, bauxite and LNG. These are multi-billion dollar investments, using some of the best technology in the world in some of the most inhospitable environments in the world. The return on this investment is directly linked to the price of the commodity being shipped and the amount of that commodity that can be handled.

It is the issue of the pressure to continually increase terminal throughput that is of immediate concern.

The shore based technology has substantially improved to provide more effective, capital intensive bulk cargo handling solutions. However the equipment and practices on the ships (specifically on the dry bulk carriers) has not seen the same quantum of improvements. In addition the drive to manage costs has seen the emergence of marine certification arrangements and crewing practices that bring into question the real ability of some crews to competently manage those ships even when things are going well.

The loading of bulk carriers is a busy time for a ship's chief mate. As the officer in charge of the entire loading operation, it is the chief mate's responsibility to make sure that the ship loads within the allotted period of time and that any problems in loading, including those associated with deballasting, are minimal and have little impact on the loading schedule. Any delays can result in the ship missing a tide, changes to the loading operation, financial consequences and other flow-on effects.

Therefore, it is common for chief mates to work longer hours when loading than they would otherwise work when the ship is at sea or discharging.

Shen Neng 1 was not the subject of any ship vetting system²⁰ inspection and there was no bonus system in place for the senior officers, which might have been put at risk if the ship's loading was delayed by anything that was caused by the ship. However, there would have been implications, both operational and financial, for the ship if the loading was delayed while the ship was alongside the berth. It is only natural that *Shen Neng 1*'s chief mate would be concerned about any adverse outcome of a delay in loading.

The chief mate maintained regular sea watches while the ship was at anchor off Gladstone. He was able to get sufficient rest in between those watches and other duties he undertook, to ensure that he was well rested. However, on the three nights immediately before the pilot boarded the ship for the transit into Gladstone, his concern that the loading progressed without delay resulted in him working an additional 3 hours each night before going to bed, coming back on watch at 0400 the following morning after obtaining about 4 hours sleep. While this routine might have had some impact on his rest hours, he was still getting a regular amount of rest.

The loading in Gladstone was to be the chief mate's first loading operation on the ship. He initially planned the loading at a nominal loading rate of 6,000 tonnes per hour. This was revised down to an average of 5,200 tonnes per hour when the ship berthed. While the chief mate was confident that the ship's ballast system could keep pace with the expected 5,200 tonnes per hour loading rate, he was unfamiliar with the ballast system. As a result, he was very concerned that if an unexpected problem arose with the ballast system, the loading might be delayed.

This was a legitimate concern and his method of managing the risk was to stay awake for the majority of the time that the system was being used to deballast the ship. As it turned out, the eventual average loading rate was only about 3,200 tonnes per hour²¹, well below the initial planned rate, and the ballast system proved to be reliable and the chief mate was able to get a little sleep at about 0100 on 3 April.

The chief mate probably thought he was doing the right thing by spending extra duty time after his evening anchor watch reassuring himself that the various figures and calculations he carried out were correct. However, by doing so, he was putting himself in the situation where his ability to properly carry out his job was beginning to be compromised by his increasing level of fatigue.

The chief mate's fatigue levels further increased on 2 April. He was woken earlier than usual to supervise weighing the anchor and, as a result, he was on duty from about 0230 that morning until 0100 on 3 April, when he went to bed during the final stages of loading. He then slept for about 2 hours. Later that day, while he had the opportunity to sleep for up to 3 hours after lunch, he only actually slept for about 30 minutes.

²⁰ An in-depth assessment of a ship's quality and suitability for a task. It is the best way to match available vessels to the operational requirements of the voyage and the need to properly manage risk.

²¹ Based on the fact that the ship loaded 68,052 tonnes of coal in about 21 hours.

Consequently, after departure on the afternoon of 3 April, when the chief mate relieved the second mate on the ship's bridge, the chief mate had slept for only 2½ hours in the previous 38½.

2.4 Fatigue

In the context of human performance, fatigue is a physical and psychological condition that is primarily caused by prolonged wakefulness and/or insufficient or disturbed sleep. Fatigue can result from a number of different sources, including time on task, time awake, acute and chronic sleep debt²² and circadian disruption²³, or a combination thereof.

Fatigue can have a range of effects on human performance: slowed reaction time; decreased short-term memory; reduced attention; decreased work efficiency; reduced motivation; increased variability in work performance; and increased errors or omission.

Reviews of fatigue research have made the following observations:

- a common symptom of fatigue is a change in the level of acceptable risk that a person tolerates, or a tendency to accept lower levels of performance and not correct errors;
- most people need 8 hours sleep each day to achieve maximum levels of alertness and performance;
- fatigue is cumulative; and
- there is a discrepancy between self-reports of fatigue and actual fatigue levels, with people generally underestimating their level of fatigue.

While many of these symptoms generally only appear after substantial levels of sleep deprivation, even the loss of sleep for one night can have negative effects on several aspects of human performance.

An analysis of seafarer survey data dealing with the impact of fatigue on cognitive functioning and safety (errors of attention, memory and action), contained in a Cardiff University seafarer fatigue study²⁴, shows that:

...those who reported high levels of fatigue were at a greater risk of making frequent cognitive failures. Frequent cognitive failures were also more likely to be reported by: those doing shorter tours of duty; those doing 6 or 12 hour shifts; those with poor sleep quality; those exposed to physical or environmental hazards; those with high job demands; those with high levels of stress at work; officers; and older workers.

These findings suggest that, as well as general fatigue risk factors, seafaring is subject to additional specific fatigue risk factors that are particularly linked to poorer cognitive function.

²² The difference in the sleep needed over a period of time and the sleep actually obtained.

²³ Factors which affect the normal 24 hour cycle of body functioning.

²⁴ Smith, A. Allen, P. Wadsworth, E. *Seafarer fatigue: The Cardiff Research programme*. Centre for Occupational and Health Psychology, Cardiff University. November 2006, pg 45.

Ships are dynamic work environments which operate 24 hours a day and do so with small numbers of crew. Consequently, the potential for fatigue in seafarers is high.

2.4.1 The chief mate's level of fatigue

Outward signs of fatigue

When considering the actions of the chief mate from when he took over the watch at 1600 on 3 April to when the ship ran aground, it can be seen that his watchkeeping performance was degraded and that he made a succession of errors. Together, this resulted in him not altering the ship's course at the position which would have seen it safely transit the passage between the Capricorn Group and Douglas and Guthrie Shoals.

The chief mate did not establish an approximate time of course alteration (1642), instead relying on what he thought would be the time (1700) based on a glance at the relative positions on the chart in use. He positioned himself in a part of the bridge where he could observe the radar and look out of the bridge windows. He did not actively move around the bridge to properly familiarise himself with the navigational task at hand, the appropriateness of the chart on the chart table or the environment outside the bridge. He also did not fix the ship's position after the chief engineer left the bridge just after 1630.

In addition, he was relying on getting a GPS waypoint approach alarm prior to the course alteration position, forgetting that the second mate told him that the amended waypoints were not entered in the GPS route plan.

The actions and inactions of the chief mate during the time leading up to the ship grounding indicate that his level of performance had deteriorated. This deterioration was probably the direct result of his lack of sleep.

In addition, during interview, the chief mate told the ATSB investigators that he was tired when he went on watch at 1600 on 3 April. While this type of 'self reporting' is sometimes inaccurate, on this occasion, it adds credence to the fact that his performance was below that of someone who was well rested.

Fatigue Avoidance Scheduling Tool (FAST)

In order to help determine whether the chief mate's level of alertness and performance was affected to any degree by fatigue, his work and rest history for the 4 weeks leading up to the grounding was assessed by the ATSB using the Fatigue Avoidance Scheduling Tool (FAST), a bio-mathematical model developed to assess fatigue/alertness, and the possible effects of fatigue on performance.

FAST was originally developed for the United States Air Force. The software was designed to assess and forecast performance changes induced by sleep restriction and time of day. FAST predicts effective performance using calculations developed from empirical research findings of studies into the effects that wakefulness and circadian rhythms have on cognitive performance.

FAST outputs an individual's overall 'fatigue/alertness score', and allows input for hours awake, periods of sleep and the quality of sleep. The biomathematical calculations used in FAST were designed to establish a score denoting an individual's task effectiveness.

The data used to assess the chief mate was derived from his hours worked record sheet and information he provided in relation to his periods of sleep when interviewed by the ATSB investigators.

The task effectiveness output from FAST shows that the chief mate's performance in the days leading up to loading in Gladstone would have been fairly constant. However, he started to experience degradation in his performance level when he began to work on the loading calculations after his evening anchor watch from 30 March onward.

The FAST calculations indicated that the chief mate's performance level would have deteriorated further during the ship's stay in Gladstone as a direct result of his lack of sleep.

The FAST assessment indicates that, at the time of the grounding the chief mate's:

- effectiveness²⁵ had fallen below the level that is defined in FAST as being 'acceptable for operations',
- his cognitive performance, as a function of alertness, would have been degraded,
- he had accumulated a large sleep debt of approximately 16.5 hours, and
- his reaction time was likely to have been almost twice the time of a well-rested person.

Most significantly, the analysis indicated that there was more than a nine-fold increase in the likelihood of him having a lapse in attention relative to a well rested person.

Overall, the FAST assessment indicates that the chief mate was probably performing well below his rested performance.

Conclusion

Based on the actions of, and the mistakes made by, *Shen Neng I*'s chief mate during his time on watch, and the FAST assessment of his working hours, it can be concluded that the chief mate's level of alertness and effectiveness was affected by fatigue. As a result, he would not have been able to properly perform the duties of an officer in charge of a navigational watch after the ship departed Gladstone on 3 April 2010.

2.5 Fatigue management

Since the task of watchkeeping is critical for the safe navigation of a ship, it is of paramount importance that there are processes and procedures in place on board the ship to ensure that watchkeeping officers are fit to undertake a navigational watch.

The issue of managing watchkeepers' fatigue has been considered so important that international requirements have been put in place to ensure shipping companies properly manage the hours of work of ships' watchkeepers.

²⁵ A score based on predicted speed on a psychomotor vigilance test (PVT).

2.5.1 International requirements

Standards of Training, Certification and Watchkeeping

On 1 February 1997, the 1995 amendments to the International Convention on Standards of Training, Certification and Watchkeeping (STCW Convention) and the Seafarers' Training, Certification and Watchkeeping (STCW) Code came into effect. These amendments introduced measures aimed at the prevention of fatigue in ship's watchkeepers.

Regulation VIII/1 (Fitness for duty) of the STCW Convention states:

Each administration shall, for the purpose of preventing fatigue:

- .1 establish and enforce rest periods for watchkeeping personnel; and
- .2 require that watch systems are so arranged that the efficiency of all watchkeeping personnel is not impaired by fatigue and that duties are so organized that the first watch at the commencement of a voyage and subsequent relieving watches are sufficiently rested and otherwise fit for duty.

The regulations contained in the STCW Convention are supported by sections in the STCW Code. Generally speaking, the Convention contains basic requirements which are detailed more fully in the Code.

The STCW Code is divided into two parts. Part A, application of which is mandatory, and Part B, which contains recommended guidance intended to help with implementing the Convention.

In Part A of the Code, Chapter VIII deals with standards regarding watchkeeping. Section A-VIII/1 (Fitness for duty) states:

1. All persons who are assigned duty as officer in charge of a watch or as a rating forming part of a watch shall be provided a minimum of 10 hours rest in any 24-hour period.
2. The hours of rest may be divided into no more than two periods, one of which should be at least 6 hours in length.
3. The requirements for rest periods laid down in paragraphs 1 and 2 need not be maintained in the case of an emergency or drill or in any other overriding operational conditions.
4. Notwithstanding the provisions of paragraph 1 and 2, the minimum of 10 hours may be reduced to not less than 6 consecutive hours provided that any such reduction shall not extend beyond 2 days and not less than 70 hours rest are provided each 7-day period.
5. Administrations shall require that watch schedules be posted where they are easily accessible.

With regard to taking over a navigational watch and the fatigue levels of watchkeepers, section A-VIII/2 part 3-1 (18) of the STCW Code states that:

The officer in charge of the navigational watch shall not hand over the watch to the relieving officer if there is reason to believe that the latter is not capable of carrying out the watchkeeping duties effectively, in which case the master shall be notified.

In Part B of the Code, Chapter VIII deals with guidance regarding watchkeeping. Section B-VIII/1 contains guidance regarding fitness for duty and prevention of fatigue and states:

1. In observing the rest period requirements, ‘overriding operational conditions’ should be construed to mean only essential shipboard work which cannot be delayed for safety or environmental reasons or which could not reasonably have been anticipated at the commencement of the voyage.
2. Although there is no universally accepted technical definition of fatigue, everyone involved in ship operations should be alert to the factors which can contribute to fatigue, including, but not limited to, those identified by the Organization²⁶, and take them into account when making decisions on ship operations.
3. In applying regulation VIII/1 [of the Convention], the following should be taken into account:
 - .1 Provisions made to prevent fatigue should ensure that excessive or unreasonable overall working hours are not undertaken. In particular, the minimum rest periods specified in section A-VIII/1 should not be interpreted as implying that all other hours may be devoted to watchkeeping or other duties.

2.5.2 Fatigue management on board *Shen Neng 1*

Shen Neng 1's safety management system (SMS) contained two procedures that dealt with hours of work on board. One was related to how the ‘shipboard work record’ form was to be completed and the other, ‘Provisions for Management of Working Hours onboard the Ship’, dealt with the minimum rest periods for watchkeepers and the maintenance of watchkeeping schedules.

The minimum rest period procedure was based on the fitness for duty provisions of the STCW Code (Section A-VIII/1). The words used in the procedure were virtually straight from the Code. However, the procedure did not provide the crew with any practical guidance on how to manage the fatigue levels of watchkeepers. The only guidance the procedure contained was the statement:

Authorities and responsibilities

The master is responsible for managing working hours of all crew members except the chief engineer who has no navigational watch.

While section B-VIII/1 (Guidance regarding fitness for duty) of the STCW Code is not mandatory, the information it contains is aimed at reducing the fatigue levels of watchkeepers and is therefore something shipping companies should consider for inclusion in any SMS. However, there was no reference to this section of the Code, or its intent, in *Shen Neng 1*'s SMS.

Consequently, the ship's master was expected to effectively manage the levels of fatigue or tiredness of the watchkeeping officers without the provision of any practical guidance from the ship's SMS.

²⁶ See the annex to IMO resolution A.772(18), paragraphs 2 to 4.4.1.

Fatigue management on board is a combination of providing the opportunity for rest, by governing or managing individual working hours, and then the individual taking the opportunity to sleep. To achieve this, every ship should have plans to manage watchkeeper fatigue during busy operational times. This is a normal part of managing a crew, and almost every time a ship is loading cargo in port will be a busy time for the deck watchkeepers, in particular the chief mate.

The duties of *Shen Neng 1*'s chief mate in Gladstone could not be considered to have been an overriding operational condition²⁷ because what he needed to do to ensure that the loading progressed smoothly was reasonably anticipated and foreseeable before the ship arrived in the port. The ship's master should have been aware of the possible hours of work of the chief mate because he himself had served in that role, on similar sized ships, during his career.

Therefore, contingency plans to manage the chief mate's anticipated level of fatigue should have been implemented before the ship berthed to ensure that he was not fatigued when he stood a navigational watch when the ship departed.

However, when the ship left Gladstone, the chief mate had not had the STCW stipulated minimum rest period of 10 hours in the preceding 24 hours and was therefore, by definition, 'unfit' to keep a navigational watch.

Since the ship's SMS contained no practical fatigue management guidelines, it was dependent on the master to put a system in place to ensure that the chief mate was not affected by fatigue when he stood his afternoon watch after leaving Gladstone. This could have been achieved by managing his duty hours while the ship was loading in the port or alternatively, as happens on many other ships, by the master keeping the chief mate's first watch out, or the second and third mates splitting the chief mate's watch. However, neither practice was employed on board *Shen Neng 1* to provide the chief mate with the necessary period of rest before he was called upon to keep a navigational watch.

2.5.3 Watch handover

In addition to section A-VIII/2 part 3-1 (18) of the STCW Code, section 3.2.6 of the International Chamber of Shipping's Bridge Procedures Guide²⁸ states:

The OOW²⁹ should not hand over the watch if there is any reason to believe that the relieving officer is unfit to, or temporarily unable to, carry out his duties effectively. If in any doubt, the OOW should call the master.

Illness or the effects of fatigue, alcohol or drugs could be reasons why the relieving officer is unfit for duty.

The ship's SMS procedure covering taking over a navigational watch contained similar wording to that in the relevant sections of the STCW Code and the Bridge Procedures Guide.

²⁷ Section B-VIII/1.1 of the STCW Code.

²⁸ Fourth edition, 2007.

²⁹ Officer of the watch.

When *Shen Neng 1*'s second mate was interviewed by the ATSB investigators, he stated that it was only on reflection, after the grounding, that he thought that the chief mate did look tired when he handed the watch over to him.

However, the second mate had been involved in the cargo loading operations while *Shen Neng 1* was in Gladstone. He had been a mate on ships long enough to understand the number of hours the chief mate had been on duty and that, in all probability, the chief mate was tired after the port visit. Yet, when the chief mate came to the bridge just before 1600 on 3 April, the second mate handed over the watch, fixed the ship's position at 1600 and left the bridge. He did not consider that the chief mate might be tired after the ship's stay in Gladstone and consequently, he did not question the chief mate about his fitness for duty.

Importantly, there is also an onus on the relieving officer to communicate the fact that he/she believes that they are not fit to take over the watch to the officer going off watch. However, this is unlikely to happen in the case of someone who is suffering the effects of fatigue, as they probably do not want to appear that they are unable to 'do their job'. Consequently, the decision regarding whether a crew member is fatigued should to be taken out of the crew member's hands and made by the ship's master and ships' procedures need to reflect this.

This case is a good example of this in that *Shen Neng 1*'s chief mate did not say anything to the second mate about feeling tired. When he got to the bridge, he acknowledged the information the second mate gave to him, looked at the chart on the chart table and then went to the starboard side of the bridge and positioned himself where he could see out the front bridge windows and the radar display.

2.5.4 On board records for hours of work and rest

Of *Shen Neng 1*'s two SMS procedures relating to fatigue, one provided directions on how the 'shipboard work record' form was to be completed by all the crew members. The procedure stated:

- 1.7 Shipboard work record should be recorded daily and maintained ready for inspection by a PSC inspectors and any of authorities.

The chief mate had filled out a work record form from when he joined the ship in Korea up until 31 March 2010, in accordance with the above requirement. He had not recorded any hours since 31 March.

On each day since joining (with the exception of two), the chief mate had recorded only the hours he had spent on watch as the hours he worked that day (Figure 9). This totalled 8 hours per day, with the remaining 16 hours each day being recorded as hours of rest. On the other two days, he recorded an additional hour of work on one day (9 March) and an additional 30 minutes of work on another (14 March).

These additional times were either before his morning watch or after his evening watch and not during normal working hours on board; 0800 to 1700.

However, it is usual and recognised practice that, for a chief mate to properly fulfil his role as head of the deck department, he has to work additional hours outside the 4 to 8 morning and evening navigational watches while the ship is at sea or at anchor. These additional hours are usually between 0800 and 1200, which enables the chief mate to oversee deck operations and then get some rest after lunch, before going on watch again at 1600.

The SMS focused on the regulatory requirements of the STCW Convention and Code which necessitates a work record being kept and a watch schedule being displayed, i.e. documents which show compliance and which are regularly checked during ISM audits or port state control inspections.

In their submission, Tosco Keymax International stated that:

At the time of the grounding, the vessel's Safety Management System was, and continues to be, approved by the Government of the People's Republic of China as being compliant with the requirements of the International Safety Management (ISM) Code. The ship's SMS contained fatigue management and passage planning procedures in compliance with industry standards and international regulations.

Despite the ship's SMS being approved by the Chinese maritime administration, it did not contain any guidance to assist in, or requirement for, the active management or review of ship operations and watchkeeper duty schedules which could lead to raised fatigue levels in a particular crew member, in this case, the chief mate.

Shen Neng 1's SMS did not support the requirements, or the intent, of the STCW Convention in relation to fatigue management. Previous audits of the SMS did not highlight the fact that there was no proper guidance provided to the master or crew with regard to how their fatigue levels should be managed and when someone should make the fact known that they might not be fit to undertake a navigational watch.

The lack of proper fatigue management guidance in *Shen Neng 1*'s SMS meant that the individual crew members were largely responsible for managing their own fatigue levels. However, the crew members simply did their job and recorded their hours of work in a way which would not reflect badly on themselves, the master or the ship managers.

2.6 Taking over the watch

Section A-VIII/2, part 3-1 (20) and (21) of the STCW Code highlights the tasks relieving officers should undertake when taking over a navigational watch at sea. Part 3-1 (20) states:

Prior to taking over the watch, relieving officers shall satisfy themselves as to the ship's estimated or true position and confirm its intended track, course, speed, and UMS controls as appropriate and shall note any dangers to navigation expected to be encountered during their watch.

These requirements are also reflected in section 3.2.6 of the Bridge Procedures Guide.

Shen Neng 1's SMS procedure for taking over a navigational watch contained similar wording to that in the relevant sections of the STCW Code and the Bridge Procedures Guide. This included the need to note 'the navigational hazards expected to be encountered during the watch'.

In addition to this guidance, if it is known that a course alteration is expected during a watch, it is recognised as good navigational practice for the relieving watchkeeper to become familiar with exactly when the alteration position will be reached. In doing so, the watchkeeper is prepared for the alteration and is less likely to be distracted by other tasks that should also be performed while on watch.

This is particularly important if the course alteration is required early in the watch, as the watchkeeper does not have the time to settle into the watch. It is also particularly important when the ship is navigating in areas where the margins of error to overshoot a course alteration are limited.

At about 1600 on 3 April, *Shen Neng 1*'s second mate pointed out the amendment to the passage plan before he handed the watch over to the chief mate. However, he did not indicate to the chief mate that the ship was due to alter course about 45 minutes into the watch. He probably assumed that the chief mate would come to that conclusion when he familiarised himself with the situation after the second mate had left the bridge. The 1600 position was on the chart, as was the course alteration position, and both positions could be easily identified.

Consequently, after the handover, the chief mate knew that the ship was due to alter course early in his watch. He could easily see the relative distance between the 1600 position and the course alteration position. However, he wrongly estimated that the ship would reach the alteration position at about 1700. He did not verify the ship's position by checking the GPS fix that the second mate had just put on the chart. Nor did he measure the distance between the 1600 position and the alteration waypoint or otherwise establish an approximate course alteration time.

When the chief mate took over the watch, he did not follow any of the guidance provided to him in the ship's procedures, the STCW Code, the Bridge Procedures Guide or the good practice of seamanship.

Furthermore, the chief mate did not fix the ship's position at or around 1630. Had he done so, he would probably have become aware that the ship was due at the course alteration position at about 1642, not 1700 as he originally concluded. However, he was distracted when the chief engineer came onto the bridge at 1630 and did not fix the ship's position after the chief engineer left the bridge. Consequently, he continued to think that he would need to alter course at about 1700 and did nothing to confirm it.

It was not until the chief mate went to put the 1700 GPS position on the chart that he realised the ship was entering an area of danger. He attempted to turn the ship to starboard but this action was too little, too late, and the ship grounded less than 5 minutes later.

2.7 Passage planning

2.7.1 The original passage plan

Shen Neng 1's passage plan for its departure from Gladstone to exit the Great Barrier Reef (GBR) took the ship through the passage to the north of the Capricorn Group. This passage was within the Designated Shipping Area (DSA) of the GBR Marine Park and could therefore be transited by ships. There was no requirement for the ship to have a pilot on board and there was no requirement to report to any shore based monitoring authority, like the GBR and Torres Strait Vessel Traffic Service (REEFVTS).

The passage was deep, ranging in depth from about 40 m in the west to 60 m in its eastern approaches. In the west, the distance between Douglas Shoal and Tryon Island was 11.2 miles and in the east, the distance between Guthrie Shoal and North

Reef was 7.5 miles. Even taking the limit of the DSA into account, the distances were considerable: 8.7 miles and 6.9 miles respectively (Figure 11). There was more than adequate sea room, with easily identifiable navigation aids, in the passage for ships to take avoiding or corrective action in the event of unexpected encounters.

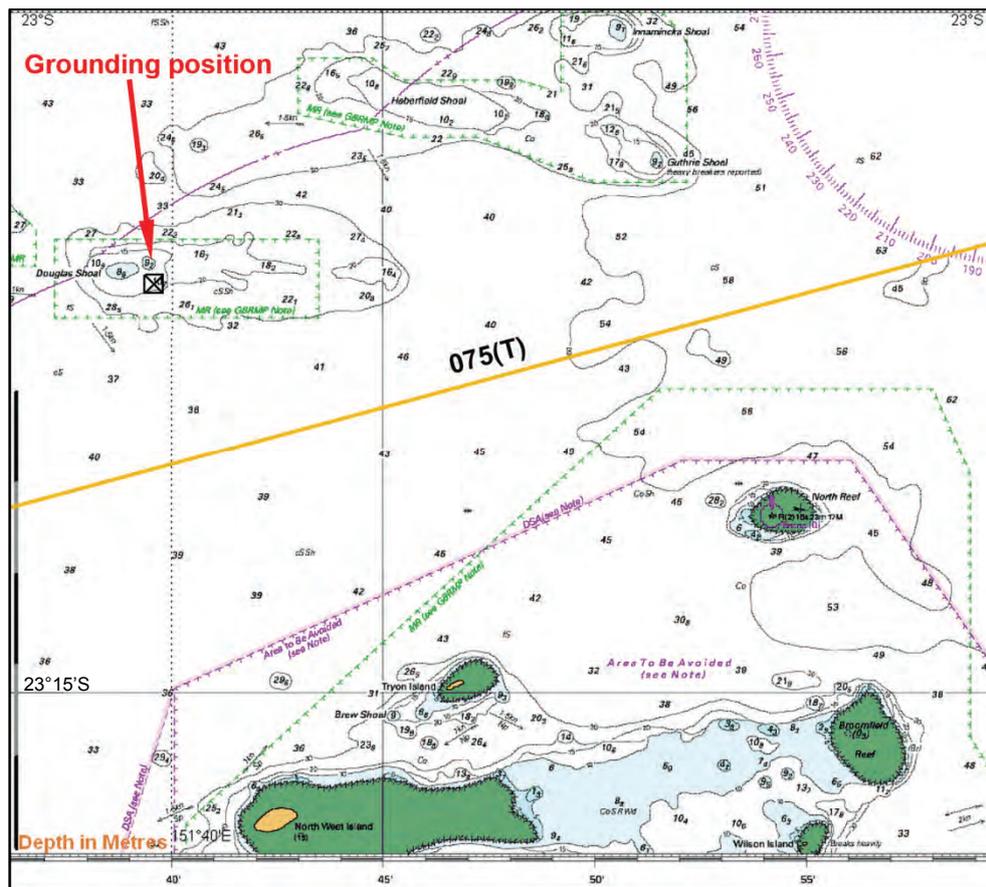
Consequently, the task of navigating a ship in this passage is relatively straightforward, provided the watchkeeper on duty was fit to be in charge of a ship, was competent and followed the practices of good seamanship.

In support of this, AMSA, in a statement released at the time of the grounding, stated:

A competent and alert watch-keeping officer should be able to navigate easily in this area.

This area is considered not navigationally challenging and there are no 'recommended routes' as there is sufficient sea room to manoeuvre the ship to avoid collision, water depths of approximately 40 metres and navigation aids to assist in position fixing.

Figure 10: Section of navigational chart Aus 820 showing *Shen Neng 1's* planned course through the passage



This passage is regularly used by ships³⁰ and *Shen Neng 1* had used the passage for its arrival at Gladstone on 24 March. The ship's outward passage plan followed the

³⁰ See Appendix A.

reciprocal courses of those used on the inbound passage. The 075° (T) course would take the ship along the centre of the passage, well clear of any navigational dangers and the DSA and 'area to be avoided' limits (Figure 10). The ship would then exit the GBR Marine Park through the Capricorn Channel and into the Coral Sea.

2.7.2 Changing the passage plan

The second mate's amendment to the passage plan after the ship departed Gladstone was minor and not uncommon. Ships' passage plans are regularly altered en route, when the time of day, visibility, traffic density, state of tide, etc. are taken into account. These changes usually take place without any adverse consequences.

The change in the course from 000° (T) to 020° (T) at 1530, in itself was not problematic. The new course and resultant waypoints were clearly indicated on the charts, as was the 'change of chart' annotation on chart Aus 819 (Figures 5 and 6). However, making a significant change to the passage plan required entering the new waypoints into the GPS unit which held the 'electronic passage plan' (route plan).

The use of route plans in GPS units is now common practice. The ability of various pieces of bridge equipment to integrate means that these route plans can be a valuable source of information for the watchkeeper, especially if a ship is equipped with an electronic chart display or a radar that displays route information.

While good watchkeeping practice dictates that watchkeepers should always carry out their duties on the bridge without an over reliance on any particular electronic navigation aid(s), the appropriate use of these aids can increase a watchkeeper's situational awareness. Their use should be properly managed and consistent with that of other navigation aids, like paper passage plans and courses drawn on charts.

In essence, if the route plan is being used, then the information it contains should be up to date and accurate. The route and passage plans should reflect the same information.

The passage planning guidance in *Shen Neng 1*'s SMS directed that appropriate information, including areas of dangers and courses to be followed, be displayed on the navigational charts. There was no requirement for any route plans to be used. Consequently, there was no requirement for any amendments to passage plans to be reflected in the route plan.

While there was no requirement for *Shen Neng 1* to have a route plan, it did and the route plan should have matched the plan displayed on the paper charts. Because it didn't, the GPS unit continued to display the original 000° (T) course as the ship moved along the 020° (T) course. This had the effect of rendering the monitoring capability of these electronic aids to navigation ineffective for this leg of the voyage. While this may have seemed inconsequential at the time to the second mate, the defences that these electronic navigation aids offered the watchkeeper were rendered useless.

2.7.3 Ineffectiveness of the GPS defences

Route plans and cross track error (XTE) monitoring are standard features of shipboard GPS units. By entering voyage waypoints in the GPS unit as well as the usual navigation system, in this case the paper charts and the passage plan, the GPS unit can provide an independent route monitoring capability, including warning the

watchkeeper when the ship has moved a nominated distance off the course, i.e. the XTE. In *Shen Neng 1*'s case, on 3 April the XTE alarm was set at 3 cables.

Additionally, the ability to have a waypoint approach alarm set so that it warns the watchkeeper of the ship's impending arrival at a waypoint is particularly useful, especially if that particular waypoint is a course alteration position. In *Shen Neng 1*'s case, on 3 April this alarm was set at 2 cables.

At 1530 on 3 April, the second mate altered the ship's heading to bring it around onto the 020° (T) course. Shortly afterwards, the XTE alarm sounded, highlighting the fact that ship had moved 3 cables off the 000° (T) course, and the second mate acknowledged the alarm.

Acceptance of the XTE alarm meant it would not sound again: it gave a 'once-only' warning and would not 're-alarm' unless the ship returned to the original 000° (T) route and then moved away from it again. Alternatively, the XTE alarm would have been reset by a change in the programmed route from the 000° (T) course to the 020° (T) course.

Consequently, because the new waypoints had not been entered into the GPS route plan, neither the XTE alarm nor waypoint approach alarm would sound as the ship followed the new 020° (T) course.

If the GPS route plan had been amended to match the passage plan, the waypoint approach alarm would have alerted the chief mate at about 1642 that the ship was approaching an alteration position. He could then have altered the ship's course to starboard and followed the course line between the Capricorn Group and the shoal area to the ship's north.

However, the GPS unit's defences had been rendered ineffective and, as a result, there was no waypoint approach alarm. The chief mate continued to believe that he would not be required to alter the ship's course until about 1700 and he was not alerted to the fact that the ship had overshot the course alteration position.

2.8 The limits of the navigational charts in use

Even though the chief mate and lookout were 'looking out' the bridge windows, there were no visual cues ahead of the ship to alert them to the approaching navigation dangers. The only navigational aid in the area was on North Reef, which in the time leading up to the grounding, was about 15 miles away on the ship's starboard side. The only features which would have shown up on radar were the islands in the Capricorn Group, also on the ship's starboard side.

In addition, the sea conditions at the time did not indicate the dangers as the sea did not break over the shoals. Given the fact that the sun was low on the western horizon³¹, and that the ship was fully loaded, any change in colour due to the shallow water at Douglas Shoal and the surrounding area would not have been identifiable from the ship's bridge.

Shen Neng 1 was not equipped with any electronic navigation charts or an electronic charting and display system (ECDIS). Without any visual cues, the only

³¹ Sunset on 3 April was at 1751.

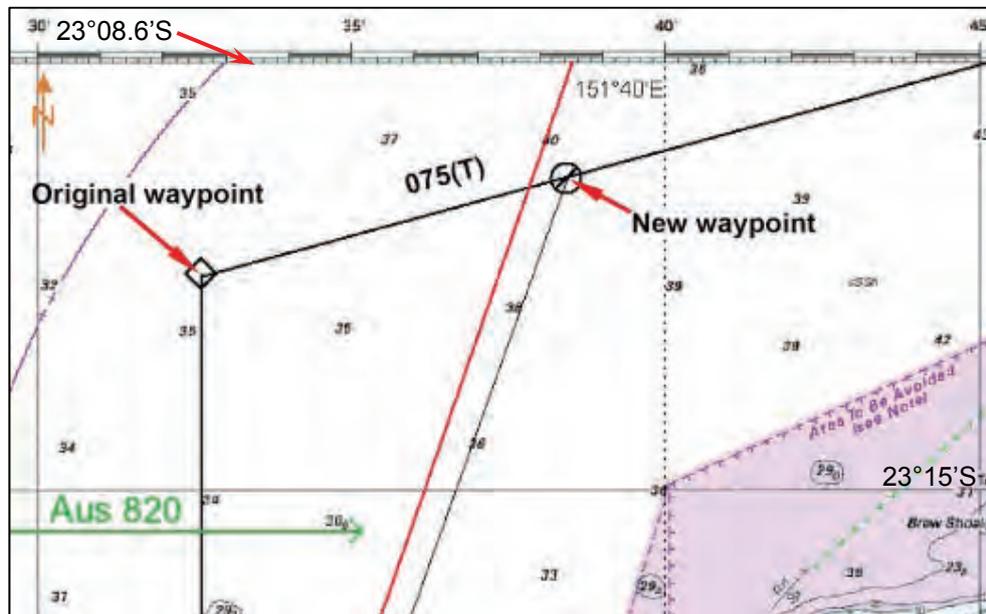
way the chief mate and the lookout could identify any dangers ahead of the ship was to use the information contained on the paper navigational charts.

The navigational charts which *Shen Neng I*'s navigating officers were to use for the ship's transit of the passage to the north of the Capricorn Group were Aus 819 and Aus 820. These navigational charts are the largest scale charts available covering this passage and were therefore the appropriate charts to use when navigating in this area of the GBR. There is also a generous overlap between the two charts which gives watchkeepers the opportunity to change charts well before a ship's entry into the passage from the south (Figures 11 and 12).

Chart Aus 819 was the appropriate chart to use for the first leg of the voyage because the chart gave coverage of the sea area from the Gladstone pilot boarding ground to the northern extremity of the Capricorn Group. However, because the chart did not give full coverage of the passage between the Capricorn Group and Douglas and Guthrie shoals, it was not the appropriate chart to be used for the transit of this area.

The northern limit of Aus 819 was $23^{\circ} 08.6'S$, about 2 miles north of North Reef. This latitude runs through the middle of the passage and does not show the sea area to the north (Figure 11). It is in this sea area that unmarked underwater navigation hazards exist. Consequently, officers who are unfamiliar with transiting the passage may not be aware of the shallow water that exists to the north of the chart's northerly limit.

Figure 11: Annotated section of navigational chart Aus 819 showing the northern limit of the chart



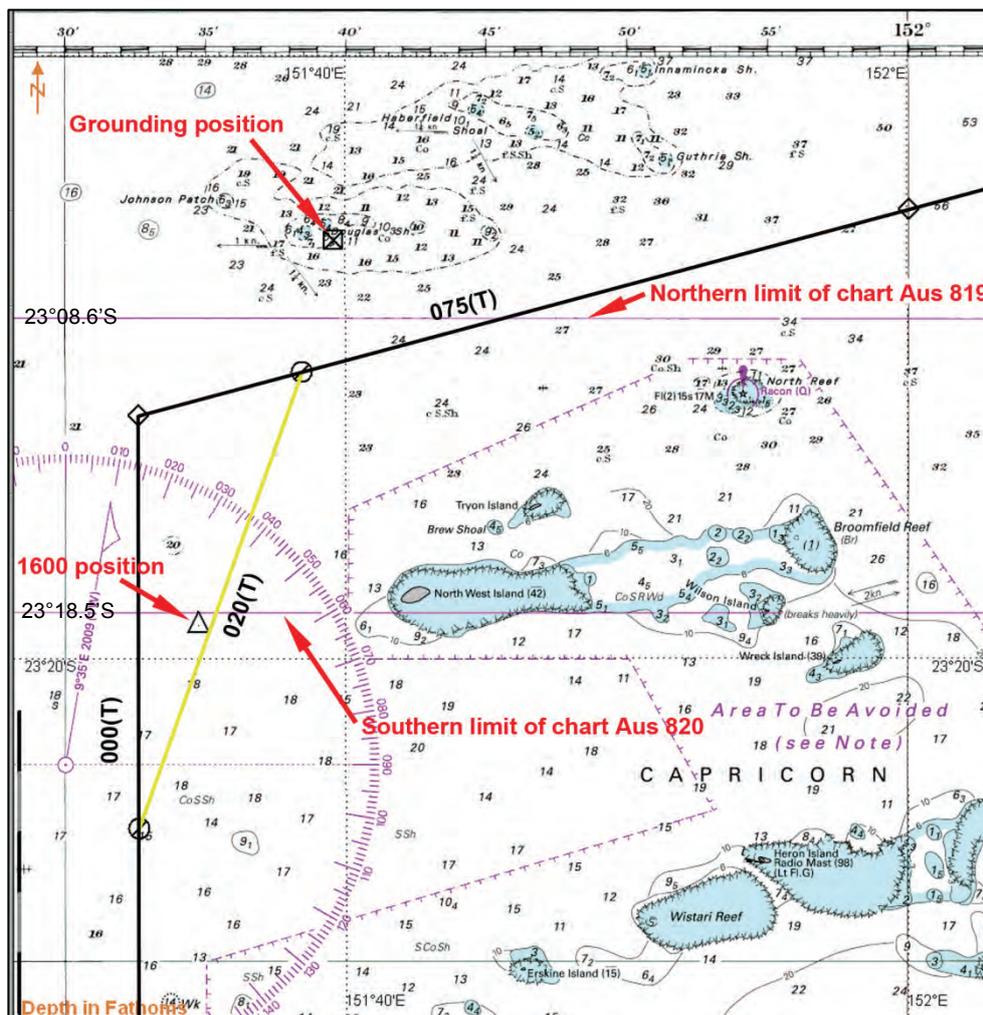
Aus 820 was the appropriate chart to be used for the transit of the passage because it provided full coverage of the area to the north of the Capricorn group including Douglas and Guthrie shoals, with the southern limit of the chart being $23^{\circ} 18.5'S$, just to the south of North West Island (Figure 12). This chart clearly shows the navigation aids and hazards on either side of this passage. Consequently, officers in charge of navigating ships through the passage using this chart are able to quickly and easily identify the risks, both above and below the sea surface.

However, when *Shen Neng 1*'s chief mate took over the watch on 3 April, Aus 819 was on the chart table. While that chart was on the chart table, he could not identify the underwater dangers directly ahead of the ship as it followed the 020° (T) course.

The second mate plotted the 1600 position on Aus 819. This position, 23° 18.8'S 151° 34.7'E, was to the south of the annotated comment 'Aus 820' and just south of the limit of Aus 820. The position was within the border region of Aus 820 and the second mate should have changed charts and transferred the 1600 position to the border region of Aus 820 before he left the bridge, as is usual navigational practice. However, when the second mate did not do this, the chief mate should have transferred the position and moved Aus 820 onto the chart table. Because of the less than adequate handover between the second and chief mates at 1600, this was not done.

Had it been done, Aus 820 would have then been left out on the chart table and any subsequent positions would have been plotted on it. As a result, the chief mate may have been alerted to the danger that lay ahead when he took over the watch.

Figure 12: Section of navigational chart Aus 366 showing the limit of charts Aus 819 and Aus 820



By 1630, the ship would have travelled to a position where the most appropriate chart to use was Aus 820. However, no 1630 position was taken and so chart Aus 819 remained on the chart table until 1700. It was only then that the chief mate changed charts and saw the dangers ahead of the ship.

Advice received from the Australian Hydrographic Services states that:

As a consequence of being a physical item, all paper charts have limits; there will always be some danger or feature just beyond the limit of every chart. The limits of Aus 819 have not altered since 1978. Since then the number of vessels to have used this reef entrance is likely to number in the thousands, all without incident. The extent of Aus 819 cannot be altered without a change of scale and loss of significant navigation detail, while simply shifting the existing chart northward to include Douglas Shoal would result in removal of the major coastal light at Bustard Head near the southern limit of the chart. This would have significant consequences for south-bound vessels in the inner route. On balance, it is therefore in the best possible position for prevailing traffic and required level of detail. Instead, Aus 819 and 820 have a generous overlap and, as the report states, Aus 820 is the appropriate chart for navigating through the reef entrance.

With respect to avoiding a recurrence of this failure to change to the appropriate chart, it should be noted that the only way this can be avoided from a systematic perspective is through use of the seamless coverage available when using Electronic Navigation Charts. Additionally, it is also worth noting that if the ship had been using an ECDIS and its safety depth/look-ahead function, alarms would have been raised well ahead of any grounding, even if the new course had not been entered into their navigation system.

2.9 Protective measures in the Great Barrier Reef off Gladstone

In comparison to the inner route of the GBR between Cairns and Cape York, where compulsory pilotage arrangements are in place, the area off Gladstone, including the passage between the Capricorn Group and Douglas and Guthrie Shoals, is relatively open and not navigationally complex. As a result, navigation of the DSAs within this part of the GBR Marine Park is straight forward provided the watchkeeper on duty is fit to be in charge of a ship, is competent and followed the practices of good seamanship.

Consequently, at the time of the incident, there was no requirement for the ship to have a pilot on board or to report to any shore based monitoring authority, like the REEFVTS.

Since the introduction of the mandatory reporting and monitoring systems in the GBR in 2004, shipping in the port of Gladstone has increased. In 2009, the port achieved a record cargo throughput of over 81 million tonnes; 58 million tonnes of which was coal, an increase of 3 per cent on 2008³². This compares to a total cargo throughput of 63 million tonnes in 2004³³.

³² Gladstone Ports Corporation media release – 10 February 2010.

³³ Central Queensland Ports Authority Annual Report 2004-05, page 8.

In coming years, ship movements to and from Gladstone are predicted to increase significantly, including ships supporting new liquefied natural gas (LNG) export facilities being planned and developed in the port.

The 2008 update to the port of Gladstone '50 Year Strategic Plan' indicates that the port of Gladstone will be able to accommodate up to 300 million tonnes of export product within the next 50 years.

This is a threefold increase in exports from the port. Consequently, the number of shipping movements near and around the Capricorn and Bunker Groups of islands is set to increase significantly. Therefore, there is a foreseeable risk posed to the GBR and its inhabitants by the forecast increase of shipping in the area.

Consequently, the protections afforded by the requirement for compulsory pilotage and active monitoring of ships by REEFVTS, two of the measures currently employed in the more northern sections of the GBR, could become more valuable in the management of the potential risks to the GBR in the Gladstone area.

As a result of the grounding of *Shen Neng 1* on Douglas Shoal, the Australian Maritime Safety Authority (AMSA) has advised the ATSB that:

Public attention has focused on requiring pilotage on these vessels in this area. The use of a pilot - an experienced master mariner, licensed by a maritime authority with expert knowledge of local conditions and ship handling, can assist a ship's master and crew in the navigation of the vessel in confined waters - has been considered by AMSA. However, the coastal waters off the port of Gladstone and the Capricorn and Bunker group of islands are relatively open and are not navigationally complex. Each year, thousands of vessels make safe passages through the area. Furthermore, introducing compulsory coastal pilotage in the area may unnecessarily increase costs, be a logistical challenge and may not be a cost effective mechanism to mitigate the risk of groundings.

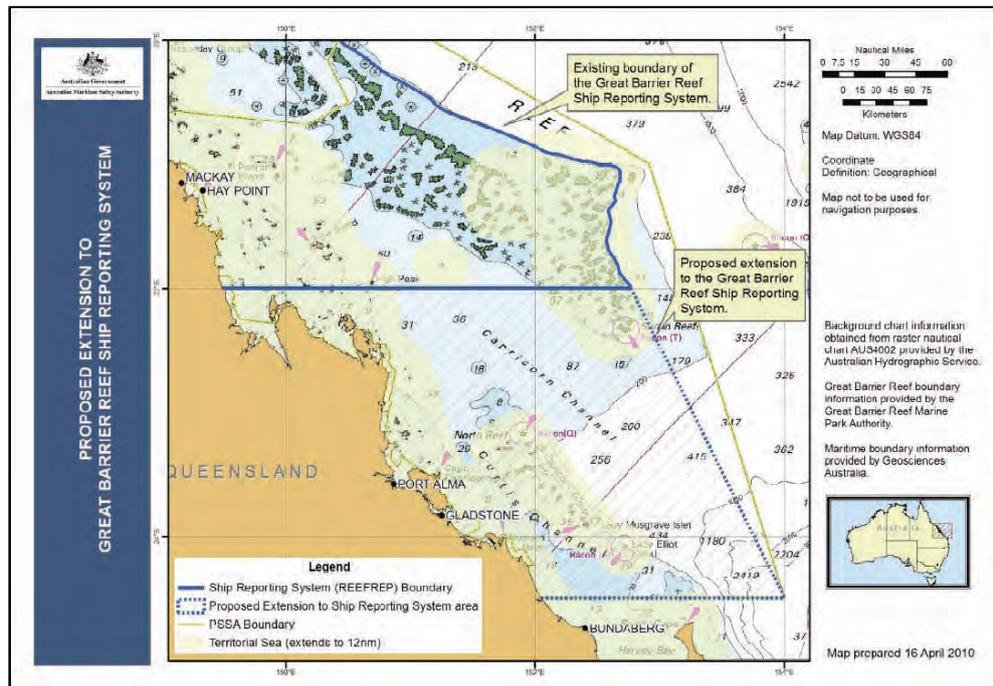
In addition, AMSA has advised that:

Vessel Traffic Services (VTS), however, do offer a cost effective mechanism and has a proven track record of mitigating the risk of groundings in waters which are not navigationally challenging. This is achieved through closely monitoring the transit of vessels and interacting with individual vessels which deviate from the recommended routes, exit electronic corridors or do not alter course at critical waypoints. VTS is able to confirm the vessel's intentions, or in situations where the vessel is standing into danger (e.g. shallow water), provide navigational assistance to avert grounding.

In April 2010, AMSA gained approval from the then Federal Minister for Infrastructure, Transport, Regional Development and Local Government to extend the coverage of REEFVTS to the southern limit of the Particular Sensitive Sea Area (PSSA) (Figure 13).

In November 2010, the IMO agreed to AMSA's proposed extension of REEFVTS coverage to in the southern boundary of the PSSA.

Figure 13: Extension of REEFVTS coverage to the southern boundary of the PSSA



2.10 Place of refuge determination and powers of intervention use

During *Shen Neng I*'s salvage operation, two place of refuge requests were put to AMSA by the salvors. The requests were made and assessed in accordance with Australia's National Maritime Place of Refuge Risk Assessment Guidelines.

These place of refuge requests were made so that *Shen Neng I* could be taken into sheltered waters for the removal of 19,000 tonnes of coal from the ship. Offloading the coal would bring the ship to a condition which would make it safe to tow the ship on a deep sea voyage to a discharge port and repair yard in Asia.

The offloading operation was to be undertaken using smaller ships, equipped with cranes and grabs, which would moor alongside *Shen Neng I*. Therefore, both ships needed to be able to lie quietly because if there was any swell present, the grabs could swing dangerously, putting the safety of those undertaking the work at risk.

Consequently, the ship could not remain off Gladstone because the anchorage did not provide the level of shelter necessary for this operation.

Gladstone

On 21 April, AMSA, acting on behalf of the Commonwealth of Australia, issued a direction³⁴ under the Commonwealth's *Protection of the Sea (Powers of Intervention) Act 1981* (as amended) designating Gladstone harbour as a place of refuge.

³⁴ An instruction which must be followed.

On 22 April, an attempt was made to move the disabled ship from the anchorage into the harbour. However, despite suitable tides, the unfavourable wind and sea conditions, combined with the poor handling characteristics of the ship, made the attempt hazardous to personnel safety and the port. Consequently, the attempt was abandoned.

Forecasts for the favourable conditions necessary for another entry attempt after 22 April were found to be unlikely and the authorities began to look for alternative locations and the direction designating Gladstone harbour as a place of refuge was cancelled.

Hervey Bay

Information provided by AMSA³⁵ regarding a second suitable place of refuge determined:

There were no practical places of refuge north of Gladstone with the necessary draft (sic) and shelter. Locations north of Gladstone are considerably further sailing and the waters become more navigationally constricted.

A place of refuge south beyond Hervey Bay would involve a lengthy voyage in unsheltered waters with the first port capable of accepting the ship being Newcastle.

Consequently, on 25 April, the salvor put forward a second request for a place of refuge in Hervey Bay. AMSA issued a direction on 29 April, identifying sheltered waters in Hervey Bay as a suitable location to conduct the offloading.

The direction was to be in place for the minimum time necessary to remove the coal from the ship. If, at any time, the operation posed an unacceptable level of risk to the environment, the ship was to be directed out of the area.

Once Hervey Bay had been determined to be the place of refuge, the first consideration was that the environmental risk the ship posed from an oil pollution perspective needed to be minimised.

According to the AMSA fact sheet release at the time:

After entry into Gladstone Port was abandoned, salvors were directed to undertake activities to remove fuel oil and contaminated ballast from the ship.

The second consideration was that the place of refuge be as far as possible from key areas of environmental sensitivity. The location selected in consultation with Maritime Safety Queensland and the Queensland Department of Environment and Resource Management is 10-15 nm north of seagrass meadows, over 30 nm north of the wetlands recognised as internationally important and 10 nm from the coast of Fraser Island.

The proposed location and the route into that location was surveyed by the MSQ hydrographic survey ship which showed no uncharted obstructions in the area and adequate water depth.

³⁵ AMSA fact sheet on *Shen Neng 1*'s place of refuge request – http://www.amsa.gov.au/marine_environment_protection/shen_neng_1_grounding/media/Shen%20Neng%201%20Hervey%20Bay%20Place%20of%20Refuge%20explanatory.pdf.

While the ships were in Hervey Bay, the salvors were directed to take all possible steps to stop coal or coal dust getting into the waters of the bay.

AMSA's use of intervention instructions to designate places of refuge during the salvage operation was appropriate and well considered.

3 FINDINGS

3.1 Context

At 1705 on 3 April 2010, the Chinese registered bulk carrier *Shen Neng 1* grounded on Douglas Shoal, about 50 miles north of the entrance to the port of Gladstone, Queensland. The ship's hull was seriously damaged by the grounding, with the engine room and six water ballast and fuel oil tanks being breached, resulting in a small amount of pollution.

From the evidence available, the following findings are made with respect to the grounding of *Shen Neng 1*. They should not be read as apportioning blame or liability to any particular organisation or individual.

3.2 Contributing safety factors

- *Shen Neng 1* grounded at 1705 on 3 April 2010, about 20 minutes after a planned course alteration, which would have taken the ship through the passage to the north of the Capricorn Group, did not take place.
- The actions of the officer on watch, the chief mate, were affected by fatigue because he did not get sufficient rest while the ship was loading in Gladstone.
- There was no effective fatigue management system in place on board *Shen Neng 1* to ensure that the bridge watchkeeper was fit to stand a navigational watch after the loading in Gladstone. *[Significant safety issue]*
- The ship's original passage plan had been amended before the grounding but the amendments were not entered into the ship's GPS unit. As a result, the cross track error and waypoint approach alarm defences the GPS unit provided had been rendered ineffective for the ship's amend route.
- The ship's safety management system did not contain procedures or guidance on the proper use of GPS route plans and their relationship to the ship's passage plans. *[Significant safety issue]*
- The chief and second mates did not follow ship and industry guidelines when they completed the watch handover at 1600. Consequently, the chief mate wrongly estimated that the ship would need to alter course at 1700 whereas the actual time for the course alteration was about 1642.
- In the 30 minutes leading up to the grounding, there were no visual cues to warn either the chief mate or the seaman on lookout duty, as to the underwater dangers directly ahead of the ship. *[Significant safety issue]*
- The second mate did not plot the 1600 position fix on chart Aus 820. Consequently, chart Aus 819 remained on the chart table and this chart did not show the underwater navigation hazards that lay ahead of the ship as it followed the 020° (T) course.

3.3 Other safety factors

- The hours of work recorded by the chief mate did not accurately reflect the actual hours he worked on board.
- At the time of the grounding, the protections afforded by a requirement for compulsory pilotage or active monitoring of ships by REEFVTS were not in place in the sea area off Gladstone. *[Significant safety issue]*

3.4 Other key findings

- The Australian Maritime Safety Authority's use of intervention directions to designate places of refuge during the salvage operation was appropriate and well considered.

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

4.1 Tosco Keymax International Ship Management Company

4.1.1 Fatigue management

Significant safety issue

There was no effective fatigue management system in place on board *Shen Neng 1* to ensure that the bridge watchkeeper was fit to stand a navigational watch after the loading in Gladstone.

Response from Tosco Keymax International

The ATSB has been advised by Tosco Keymax International that since the incident, in accordance with the company's policy of continuous improvement, Tosco Keymax has implemented additional inspection regimes and provided information and further training to ship's staff relevant to issues arising from the grounding.

ATSB assessment of action

The ATSB remains concerned that there is no proper guidance provided to the master or crew with regard to how fatigue levels should be managed and when someone should make the fact known that they might not be fit to undertake a navigational watch.

ATSB safety recommendation MO-2010-003-SR-005

The Australian Transport Safety Bureau recommends that Tosco Keymax International takes further safety action to address this safety issue.

4.1.2 Passage planning procedures

Significant safety issue

The ship's safety management system did not contain procedures or guidance on the proper use of GPS route plans and their relationship to the ship's passage plans.

Response from Tosco Keymax International

The ATSB has been advised by Tosco Keymax International that since the incident, in accordance with the company's policy of continuous improvement, Tosco Keymax has implemented additional inspection regimes and provided information and further training to ship's staff relevant to issues arising from the grounding.

ATSB assessment of action

The ATSB remains concerned that there is no proper guidance in the ship's safety management system to ensure that the defences offered by a GPS route planning system are used in conjunction with the passage plan.

ATSB safety recommendation MO-2010-003-SR-006

The Australian Transport Safety Bureau recommends that Tosco Keymax International takes further safety action to address this safety issue.

4.2 Australian Maritime Safety Authority

4.2.1 Protective measures in the Great Barrier Reef – navigation aids

Significant safety issue

In the 30 minutes leading up to the grounding, there were no visual cues to warn either the chief mate or the seaman on lookout duty, as to the underwater navigation hazards directly ahead of the ship.

Action taken by the Australian Maritime Safety Authority

The Australian Maritime Safety Authority has advised the ATSB that, as part of a package to improve safe navigation in the Great Barrier Reef, the Authority will be enhancing navigational aids, leveraging off current and anticipated technology, to assist navigation by both pilots and masters and to increase situational awareness in real time. This includes consideration of deploying navigational buoys at Douglas Shoal and Rock Cod Shoal on the route taken by the vessels transiting to and from Gladstone from the north.

ATSB assessment of action

The ATSB is satisfied that the action proposed by the Australian Maritime Safety Authority adequately addresses this safety issue.

4.2.2 Protective measures in the Great Barrier Reef - other

Significant safety issue

At the time of the grounding, the protections afforded by a requirement for compulsory pilotage or active monitoring of ships by REEFVTS were not in place in the sea area off Gladstone.

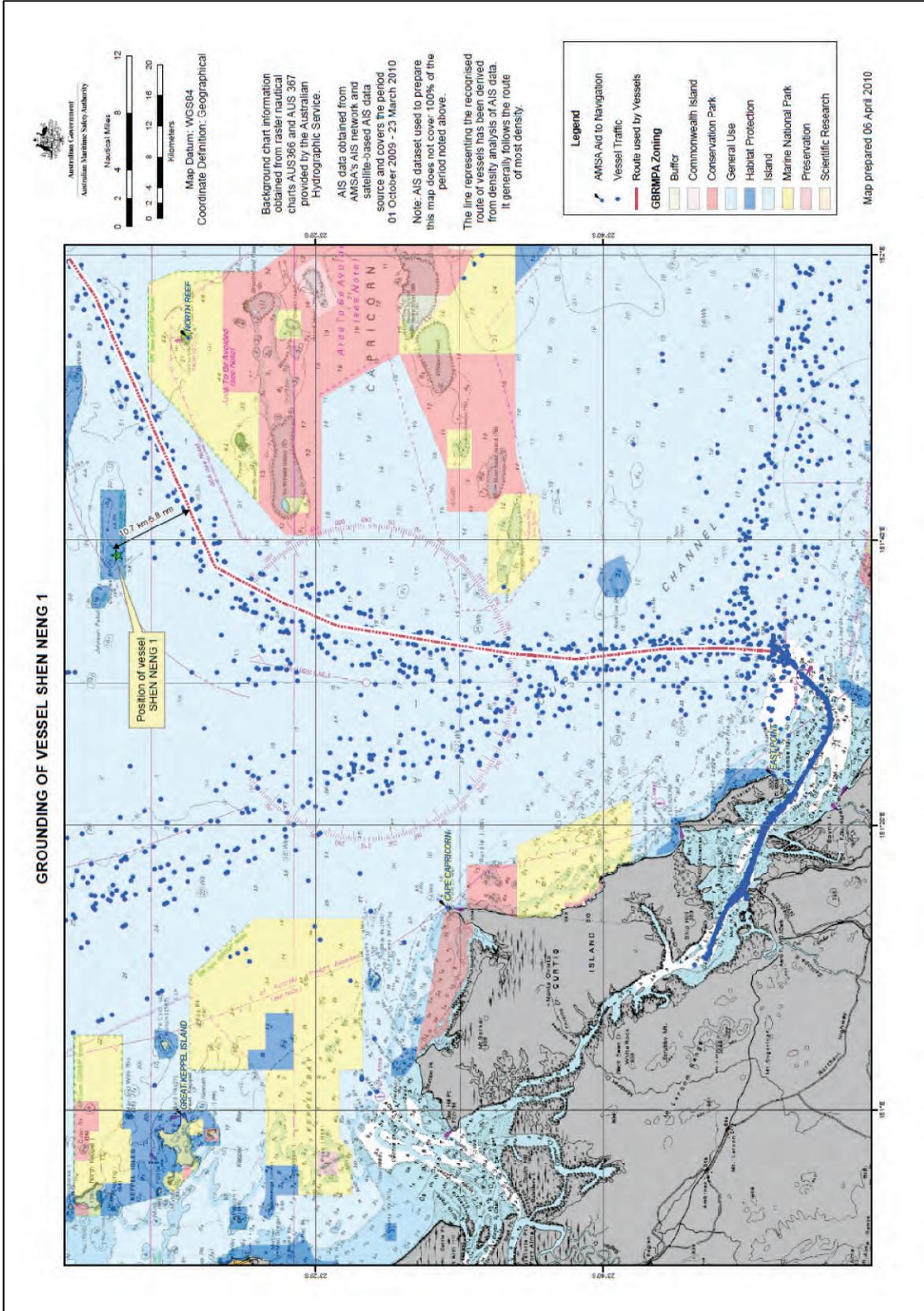
Action taken by the Australian Maritime Safety Authority

The Australian Maritime Safety Authority has advised the ATSB that, following a review of the protection arrangements within the Great Barrier Reef, the coverage of REEFVTS will be extended to the southern boundary of the Particularly Sensitive Sea Area. This will include the sea area off Gladstone and implementation will be effective from 1 July 2011.

ATSB assessment of action

The ATSB is satisfied that the action proposed by the Australian Maritime Safety Authority adequately addresses this safety issue.

APPENDIX A: GLADSTONE SHIPPING MOVEMENTS



DENSITY PLOT - AIS AROUND AUSTRALIA



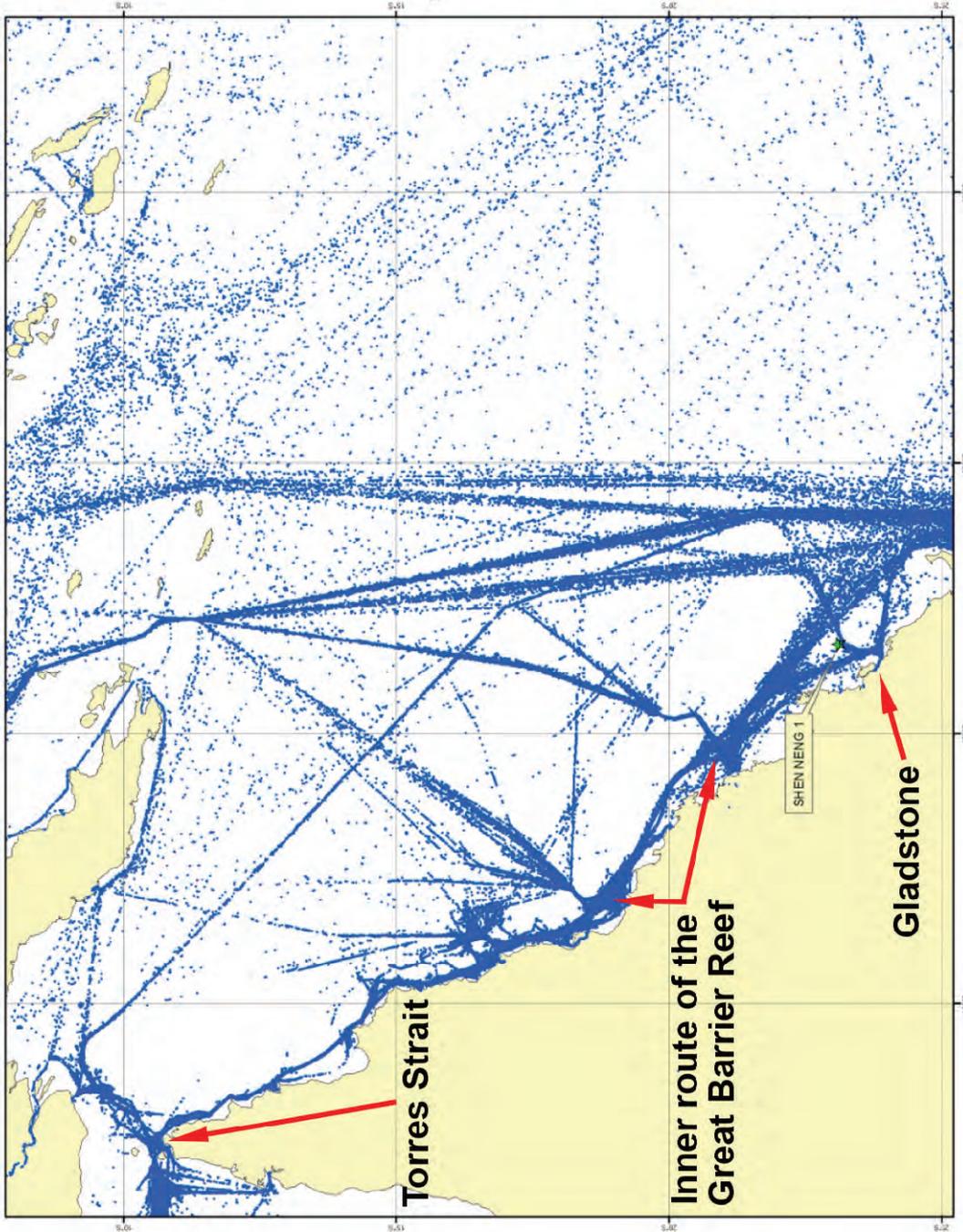
Map Datum: WGS84
Coordinate Definition: Geographical

AIS data obtained from
AMSA's AIS network and
satellite-based AIS data
source and covers the period
01 October 2009 - 23 March 2010

Note: AIS dataset used to prepare
this map does not cover 100% of the
period noted above.

The line representing the general
route of vessels has been derived
from density analysis of AIS data.
It generally follows the route
of most density.

Map prepared 06 April 2010



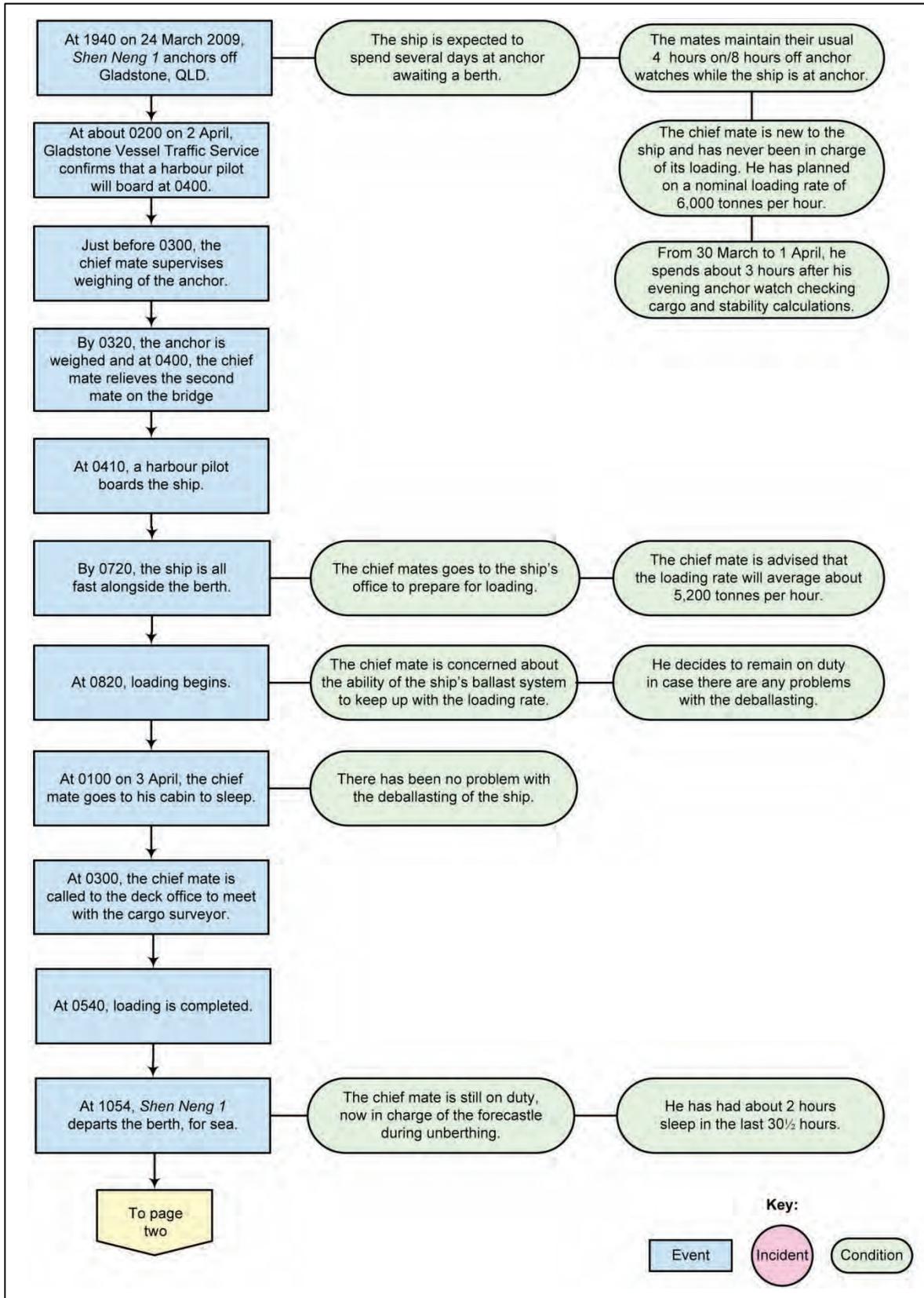
Torres Strait

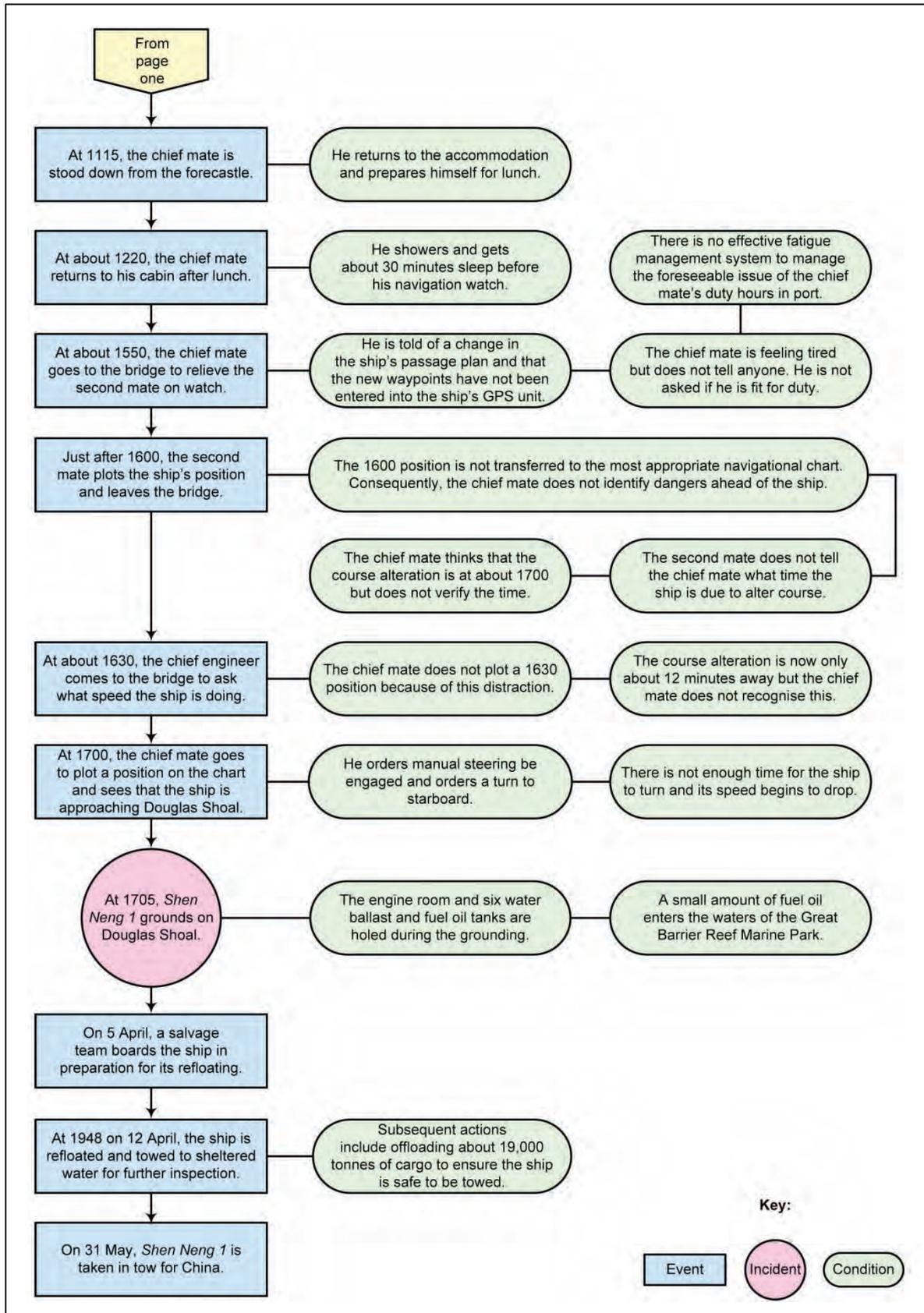
Inner route of the
Great Barrier Reef

Gladstone

SHEN NENG 1

APPENDIX B: EVENTS AND CONDITIONS CHART





APPENDIX C: SHIP INFORMATION

Shen Neng 1

IMO Number	9040871
Call sign	BXAN
Flag	China
Port of Registry	Shenzhen
Classification society	China Classification Society (CCS)
Ship Type	Bulk carrier
Builder	Sanoyas Hishino Meisho Corporation, Kurashiki, Japan
Year built	1993
Owners	Shenzhen Energy Transport, China
Ship managers	Tosco Keymax International Ship Management Company, China
Gross tonnage	36,575
Net tonnage	23,279
Deadweight (summer)	70,181 tonnes
Summer draught	13.291 m
Length overall	225.00 m
Length between perpendiculars	216.95 m
Moulded breadth	32.26 m
Moulded depth	18.354 m
Engine	1 x Sulzer 6RTA62
Total power	8,827 kW
Speed	14.0 knots
Crew	23

APPENDIX D: SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included the:

Master and crew of *Shen Neng 1*

Australian Maritime Safety Authority

Maritime Safety Queensland

Australian Hydrographic Service

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Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to *Shen Neng 1*'s master, chief mate, and second mate, Tosco Keymax International Ship Management, the China Classification Society (CCS), the Australian Maritime Safety Authority (AMSA), Marine Safety Queensland (MSQ), Svitzer Salvage Australasia (Svitzer), the Great Barrier Reef Marine Park Authority (GBRMPA), the Australian Hydrographic Service and the China Maritime Safety Administration.

Submissions were received from *Shen Neng 1*'s chief mate, AMSA, MSQ, GBRMPA, the Australian Hydrographic Service, Svitzer and the China Maritime Safety Administration. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Independent investigation into the grounding of the Chinese registered
bulk carrier *Shen Neng 1* on Douglas Shoal, Queensland on 3 April 2010