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Australian Transport Safety Bureau

AUSTRALIAN TRANSPORT SAFETY BUREAU

MARINE SAFETY INVESTIGATION

REPORT 148

Coral Sea
on 26 and 27 July 1999

COMMONWEALTH DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES

Report No 148

Navigation Act 1912

Navigation (Marine Casualty) Regulations

investigation into

the shift of cargo on board the Singapore flag bulk carrier

PADANG HAWK

in the Coral Sea

on 26 and 27 July 1999

Issued by the

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Investigations into marine casualties occurring within the Commonwealth's jurisdiction are conducted under the provisions of the Navigation (Marine Casualty) Regulations, made pursuant to subsections 425 (1) (ea) and 425 (1AAA) of the Navigation Act 1912. The Regulations provide discretionary powers to the Inspector to investigate incidents as defined by the Regulations. Where an investigation is undertaken, the Inspector must submit a report to the Executive Director of the Australian Transport Safety Bureau (ATSB).

It is ATSB policy to publish such reports in full as an educational tool to increase awareness of the causes of marine incidents so as to improve safety at sea and enhance the protection of the marine enviroment.

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PADANG HAWK

Summary

Between 17 and 23 July 1999, the Singapore flag bulk carrier Padang Hawk loaded a full cargo of nickel ore from barges at Kouaoua, New Caledonia. Late on 23 July, the ship sailed for Townsville, Australia. During the passage, Padang Hawk was subjected to rough seas and rolled heavily. At about 2200 on 26 July, the ship developed a 15° list to port.

A quick examination of the holds showed that the cargo in four of the five holds had settled and appeared to have liquefied. Some water was pooling on the surface of the cargo in number 1 hold. The cargo in the forward holds appeared to be 'flowing' with the movement of the ship.

The master reduced speed and altered course to put the wind and seas on the ship's port quarter. Ballast was then pumped to correct the list. The ship's course was maintained so that it entered the inner route of the Great Barrier Reef by Grafton Passage rather than the more southerly Palm Passage.

The ship finally arrived safely in Townsville at 2000 on the evening of 28 July.

Sources of information

The master and crew of Padang Hawk

Queensland Nickel Pty Ltd

Australian Maritime Safety Authority

LLP Ltd, Information Service Department

International Transport Workers Federation

Nippon Kaiji Kyokai Survey Department

Meteorological Office of New Caledonia

SGS Australia Pty Ltd

Professor Tamaki Ura, University of Tokyo

Marine Casualties Investigation Board, France

Queensland Department of Mines and Energy

Acknowledgement

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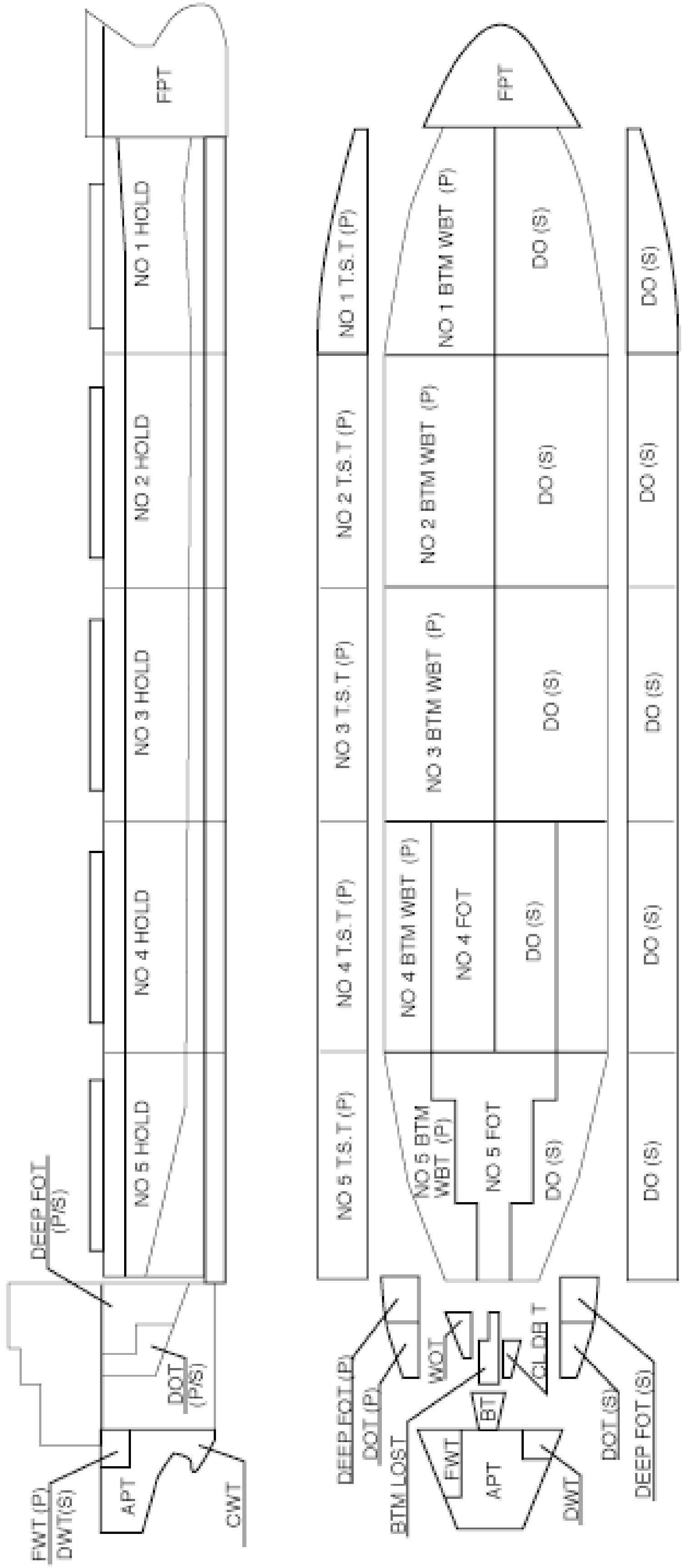
FIGURE 2.
Padang Hawk holds and tanks



Narrative

Padang Hawk

The Singapore flag Padang Hawk (figs. 1 and 2) is a 46 635 tonne deadweight 'geared' bulk carrier, owned by Singa Star Pte. Ltd. of Singapore. The ship was built in 1995 by Mitsui Engineering and Ship Building of Japan and is classed with Nippon Kaiji Kyokai (NK).

Padang Hawk is 189.8 m in length overall, has a beam of 31 m and a summer draught of 11.6 m. Propulsive power is delivered by a six-cylinder Mitsui MAN B&W 6S50MC slow-speed diesel engine developing 6 532 kW. The main engine drives a single fixed pitch propeller, which provides a service speed of

14 knots. Electrical power is provided by three Daihatsu 6DL-20 generators, each producing 480 kW.

The engine room and accommodation superstructure are located at the after end of the vessel, (aft of frame 37). There are five cargo holds; with the exception of number 1 hold at 17.6 m, all are 20.8 m in length and extend to the collision bulkhead at frame 216. The ship has four cranes to service the five holds when ship's equipment is required for loading or discharging.

At the time of the incident, the shipowners held a current International Safety Management Code (ISM Code) document of compliance for bulk carriers, issued by NK on 24 March 1998, under the authority of the Government of the Republic of Singapore. Padang Hawk had been issued with a Safety Management Certificate on 28 April 1998 by NK.

Padang Hawk is a regular caller at Townsville with cargoes of nickel ore. The ship carried a cargo of nickel ore from the port of Nakety, New Caledonia to Townsville on the previous voyage, number 903. Padang Hawk was to return to Kouaoua, New Caledonia, on voyage number 904 to load another cargo of nickel ore for shipment to Townsville.

The master and mate joined the ship at Townsville at the completion of the voyage number 903. They were both experienced in bulk carrier trades and the master had previously commanded a smaller bulk carrier carrying nickel ore on coastal voyages around New Caledonia.

The nickel ore trade

In 1986, Queensland Nickel Pty Ltd (QNPL) started importing limonitic nickel ore for its nickel and cobalt refinery at Yabulu, 25 km north-west of Townsville. The Yabulu refinery utilises nickel ore from the Philippines, Indonesia and New Caledonia. At the time of the incident, in excess of 27.4 million tonnes of ore had been carried in 577 vessels into the port of Townsville.

The Philippines, Indonesia and New Caledonia are estimated to contain 35% of the world's nickel resources. The nickel occurs in 'laterite' deposits, which have been formed by the deep weathering of ultramafic[1] rocks. Typically, the laterite deposits have an upper zone in which the nickel is combined with iron oxides (limonite zone), and a lower zone where the nickel occurs in complex magnesium-

1 Igneous rocks containing a high percentage of iron and magnesium based minerals.

rich silicates (saprolite zone) (fig. 3). Limonite generally contains around 1.5% nickel, and saprolite around 2.5% nickel.

Laterite deposits are mined using 'open cut' methods. The limonitic and saprolitic ores are mined together and the ores are graded and stockpiled separately. Mine site stockpiles generally consist of 'windrows' where the ore is dumped in rows of small piles and turned regularly to aid the drying process. Once the ore has been dried sufficiently, it is transported to larger stockpiles at the ship-loading facility. The ore in many shallow water ports, including Kouaoua on the east coast of New Caledonia (fig. 4), is loaded onto barges at the ship loading facility and transported out to ships at anchor in deeper water. The ship's cranes are then used to load the ore from the barges into the cargo holds.

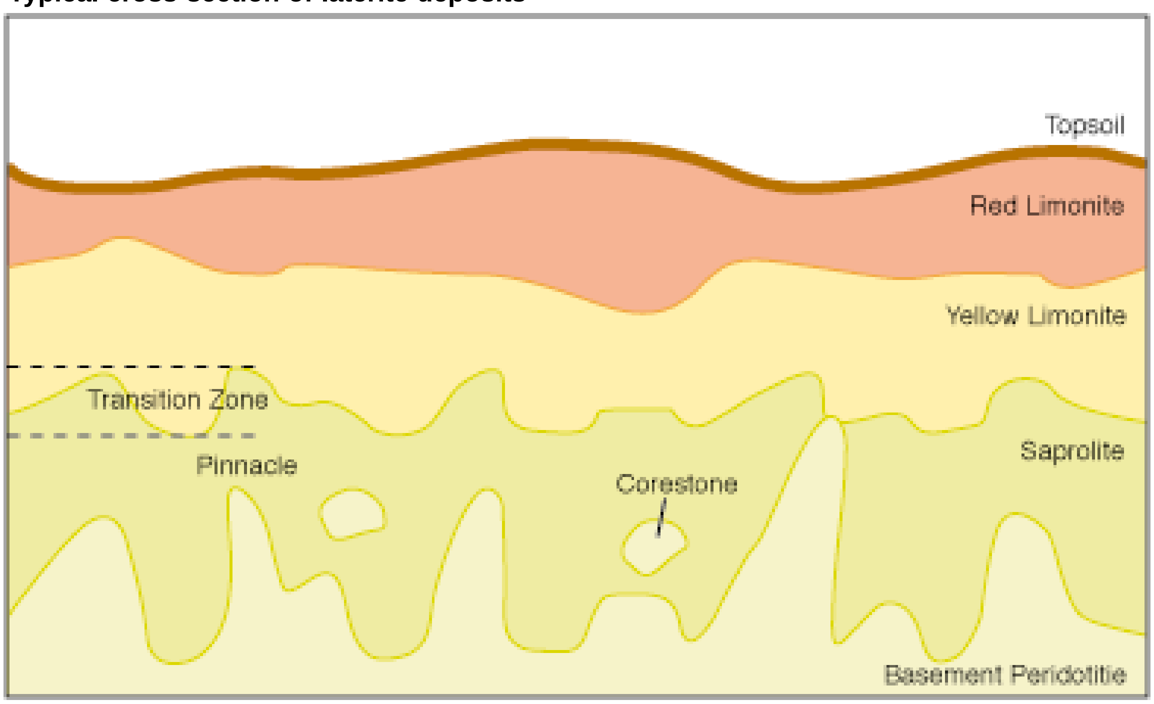
The refining processes for limonitic and pure saprolitic ores are different owing to their differing mineral properties. QNPL utilises ore largely from the limonite zone, excluding pure saprolitic ores. The ore is discharged from ships in the port of Townsville then transhipped by train to the Yabulu refinery where an ammonia leach process is used to refine the ore.

Saprolitic nickel ores are refined using a smelting process. A large proportion of the saprolitic ores mined in the Philippines, Indonesia and New Caledonia are shipped to Japan.

The incident

Padang Hawk sailed from Townsville on the evening of 13 July and arrived at the anchorage at Kouaoua, New Caledonia at 1224 on 17 July. Loading of ore from shore barges commenced at 1440. The ship's cranes were manned by shore labour and loading from the barges was carried out from about 0500 each morning until about 2030 in the evenings. With the exception of one morning, when there were a few hours of light drizzle, the weather was fine throughout the loading operation. Soundings of the cargo holds for water were taken each day and no bilge

FIGURE 3.
Typical cross-section of laterite deposits



water was recorded.

During the loading operation, the ship's crew noticed that some 'grabs' of cargo had water running from them as they were lifted out of the barges and into the ship's holds.

The cargo loading was completed at 2140 on 23 July. The crew stated that the hatches were then closed and secured by the hatch cleats. Following a draught survey, a pilot embarked and Padang Hawk sailed from Kouaoua at 2307, at a draught of 11.85 m fore and aft.

After the pilot disembarked in the early hours of 24 July, the master set a northerly course along the east coast of New Caledonia. The planned route was to take Padang Hawk north of Récifs d'Entrecasteaux, west through the Coral Sea, north of Bampton Reef and Marion Reef, to Palm Passage and Townsville (fig. 5).

At 1700 on 24 July, the bilges of all holds were pumped dry. The ships log-book records the course as 303° with the ship rolling heavily in a south-easterly swell.

The passage proceeded as planned. Just before 2400 on 24 July, north of Récifs d'Entrecasteaux, Padang Hawk altered course to a true heading of 265°, making good a speed of 13 knots. The wind was noted as being east-south-east, force 5, and the sea was described as rough. The

FIGURE 4.
Laterite deposits in New Caledonia

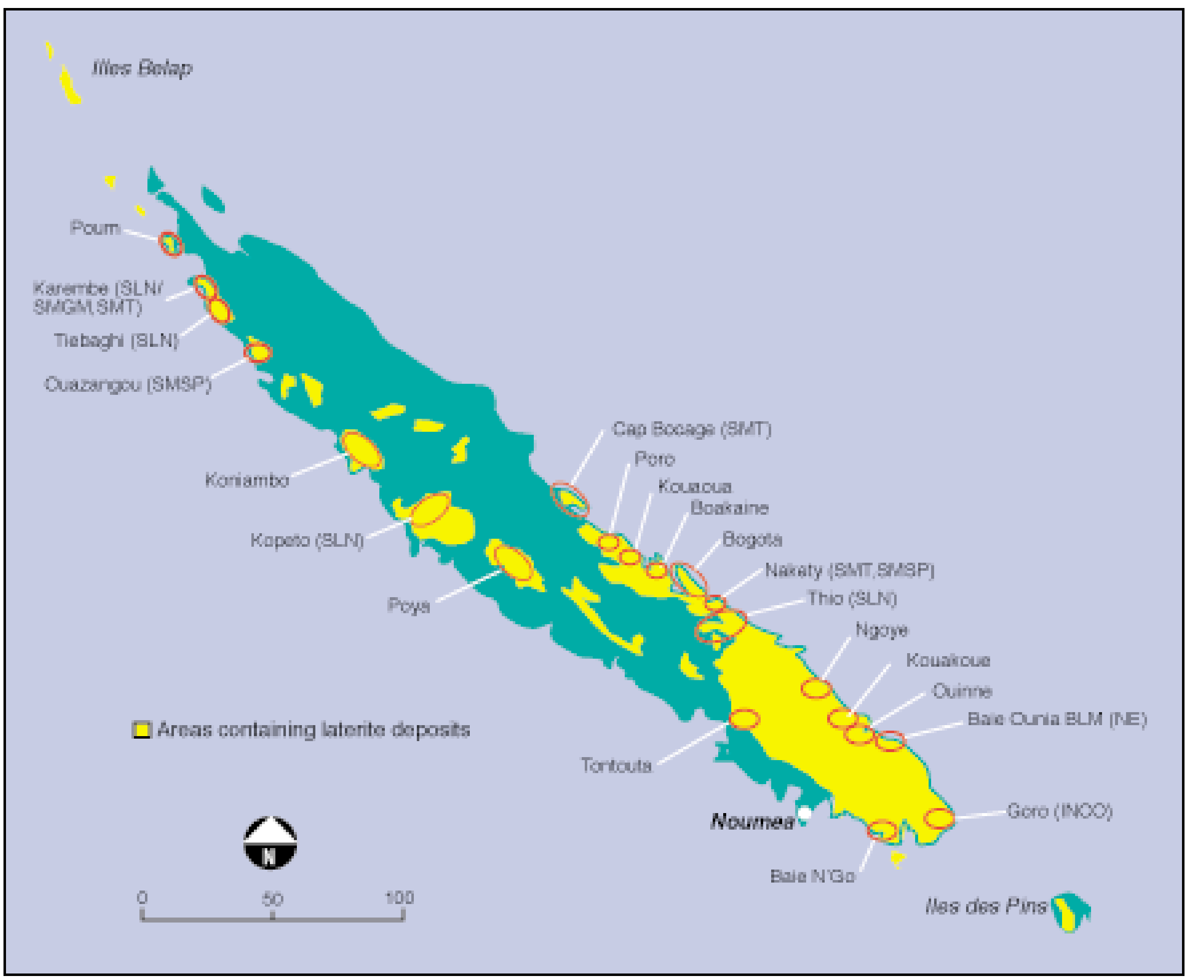
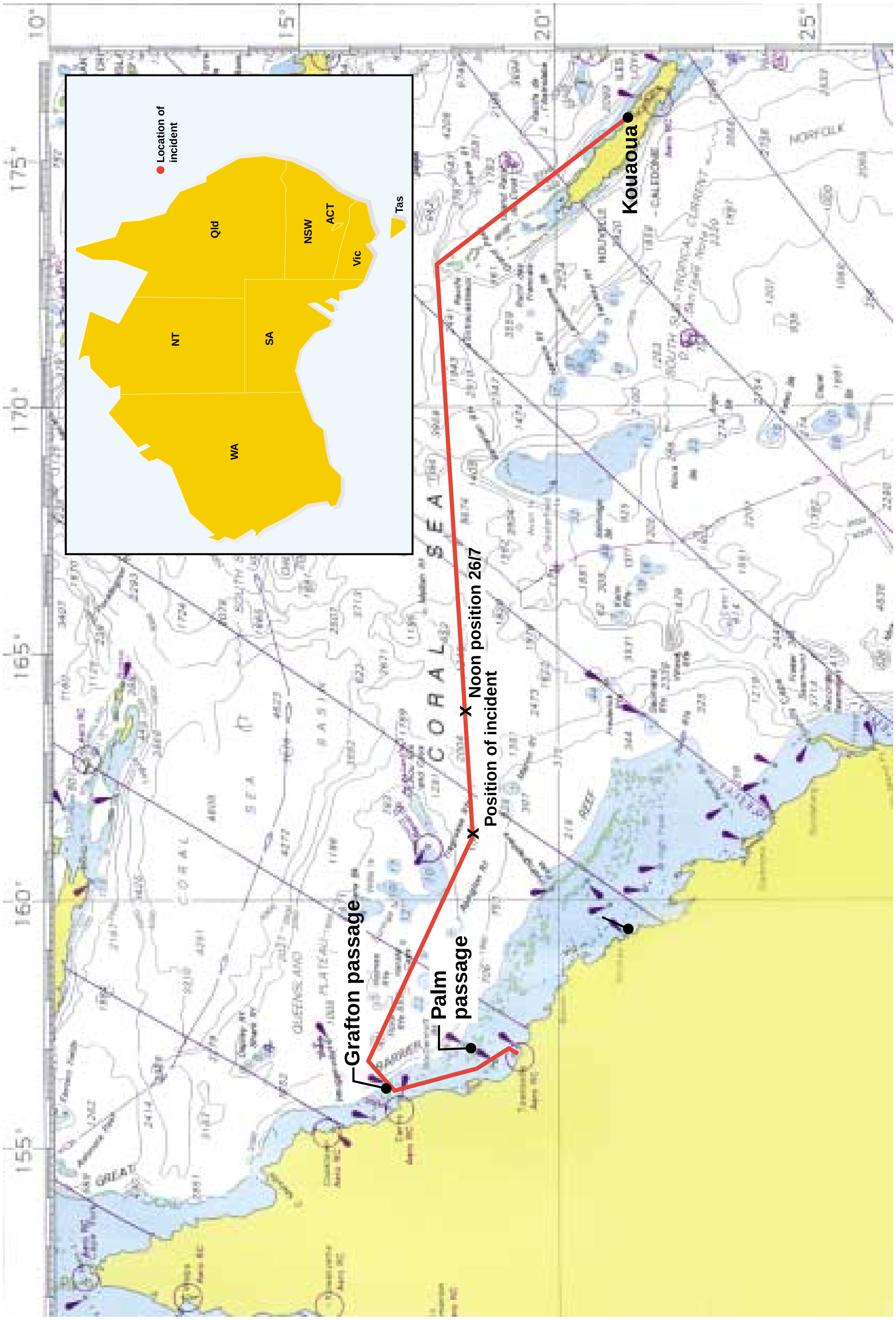


FIGURE 5.
Padang Hawk's passage to Townsville



vessel was rolling and pitching heavily in a south-easterly swell. At 0900 on

25 July, the bilges in all holds were again pumped. The rough conditions caused the vessel to roll and pitch heavily, particularly from 1600 onwards on 25 July.

At 0830 on 26 July, the bilges in all holds were pumped. The vessel was still rolling heavily in the southerly swell and strong winds that had veered to south to south-westerly. At noon on 26 July, Padang Hawk was in position 18° 11' S 153° 56' E, about 100 nautical miles east-north-east of Marion Reef. Over the preceding day, the average speed had been 12.7 knots.

During the afternoon, the wind strength was logged at force 5 with regular notations in the logbook concerning the ship's heavy rolling. Throughout the day, from time to time, seas broke over the deck and hatch covers. By 2000, the wind was logged at force 6–7 and the vessel was rolling heavily. The hold bilges were pumped at 2000 and again at 2100.

At 2200, or a little before, Padang Hawk suddenly developed a 15° list to port. The master, who was in his cabin, immediately went to the bridge and joined the second mate and lookout. The master altered course from 265° to 295° to bring the wind and sea on to the port quarter and reduced the engine revolutions from 110 RPM to 100 RPM.

The master mustered all the crew. In the dark, with seas breaking over the port side and the ship rolling heavily about the angle of the list, there was general concern and a very high level of apprehension amongst all the crew.

The master sent the mate, boatswain and some deck ratings to check the hatches and the state of the main deck. The crew checked and found the cargo hatches and the small hold access hatches secured. They opened an access hatch to each of the holds in turn. They found that the cargo in all but number 5 hold had settled and shifted to port. The cargo in the first 3 holds appeared to be semi-liquid, 'like melted ice cream' as the boatswain described it.

The master decided to ballast starboard side tanks to correct the list. Numbers 3 and 5 starboard topside tanks were filled.

The master sent a radio message to the 'designated person', as described in the ship's ISM Code documentation. The message detailed the situation and the remedial action taken. A message was also sent to the ship's agent in Townsville, who informed the Australian Maritime Safety Authority of the ship's message and the report that the cargo had liquefied.

At 0145, the master received a reply from the vessel's owners advising him to use double bottom tanks to correct the list. The message noted that countering lists by using topside tanks had caused vessels to capsize and it continued:

Although your vessel is having very high GM due to dense cargo, still high risk of cargo shifting to one side with the roll is high.

The ship's list had been reduced to about 5° by the early morning. The strong wind and heavy swell continued and seas broke regularly over the vessel's quarter. Because of the heavy swell, the master decided to wait before turning toward

Palm Passage. The cargo hold bilges were pumped at regular intervals throughout the day. The disposition of ballast was adjusted in accordance with the advice from the owners.

At noon on 27 July, Padang Hawk was at position 17° 16' S 148° 58' E. The weather had not abated and the master judged it unsafe to try and make Palm Passage, as this meant altering course to bring the wind on the port beam. He decided to maintain the course with the wind astern. Fortunately the course of 295° took the ship directly towards Grafton Passage. Even with reduced engine revolutions, Padang Hawk made good speed. In the early hours of 28 July, the ship was approaching Grafton passage and, by 0400, it was safely in the calmer waters inside the Great Barrier Reef.

In the afternoon of 28 July, Padang Hawk anchored off Townsville and final adjustments were made to the ballast to minimise the list and reduce the ship's draught. The anchor was weighed at 1737 and the pilot boarded at 1820. The ship arrived safely alongside in Townsville at 1928 on 28 July.

FIGURES 6 & 7
Cargo, hold number 1 (two views)

Comment and analysis

Initial inspection

When Padang Hawk arrived alongside at Townsville in the evening of 28 July 1999, investigators inspected the ship's cargo holds. Cargo in holds 1, 2, 3 and 4 had settled and shifted. In each hold, the surface of the ore showed that a portion of the ore had apparently 'liquefied' into a glutinous thick slurry. In number 1 hold, water was pooled on the surface of the ore and the whole cargo in this hold had settled to be almost level. The inner sides of the hold showed the cargo still 'hanging' to port, about 5.5 m below the deck level, and there was evidence of significant 'mud' splash (figs. 6, 7, and 8). The cargo in holds 2, 3, and 4 showed varying amounts of liquefaction with a central mound of unaffected cargo surrounded by cargo that had liquefied.

In number 5 hold, the cargo retained the form in which it was loaded, with cargo forming a flattened pyramid which reached to the level of the bottom of the topside hopper tank, 3.5 m below the deck level. The disposition of the cargo in number 5 indicated the way in which the cargo had been trimmed and what the cargo must have looked like in holds 1, 2, 3, and 4 after the completion of loading.

Test 'grabs' were taken from number 1 hold on the morning of 29 July, using the shore-based discharge crane. The cargo lifted in the test grabs remained in a bulk solid form, with some water or slurry running from the surface when lifted from the hold. The 'holes' left in the surface of the cargo after each grab was removed, maintained their approximate size and shape without excessive 'slump' in the surrounding cargo.

The hatch covers aboard Padang Hawk are hydraulically operated steel covers, with two sections folding and opening forward and two sections folding and opening at the after end of the hatch. The hatch seal consists of neoprene rubber packing. Locking dogs fixed at intervals around their periphery ensure that the hatch covers are watertight.

Padang Hawk presented as a well-maintained ship with hydraulic deck equipment in good order. Examination of the hatch covers, coamings and other openings into the cargo holds, showed no obvious sign of any ingress of water. The neoprene packing on the hatch covers was in good condition and showed that it had sealed against the coaming channel bar. Inside the coamings there was no obvious sign of any ingress of water, although some water was lying in the trackways associated with the hatch coamings.

Sample tests

The state of the cargo in the forward four holds was caused by excessive moisture in the nickel ore and indicated two possibilities: either seawater had gained access to the holds in the rough weather, or the cargo had been loaded in an excessively moist condition.

If the moisture present in the cargo had been due to seawater ingress through poorly secured or failed hatch covers, it would have been 'salty'. Conversely, if the cargo had been loaded in an excessively moist condition, the origin of the water would have been rain in the mining and/or stockpiling phases of the operation and would consequently have been 'fresh'.

Investigators took samples of the nickel ore from just beneath the top layer and between 20–30 cm below the cargo surface in number 1 and number 5 holds. The ore was a red sand or dust with larger pieces of solid greenish rock interspersed throughout. These larger pieces were generally less than 5 mm in size.

The samples were sealed in tins and delivered to SGS Australia Ltd, at Port Kembla for analysis to determine:

- whether or not the origin of the mois ture was sea or rain water,
- the actual moisture level,
- the transportable moisture limit[2] (TML).

To ascertain whether the cargo had been contaminated by seawater, SGS used two different tests; the Mohr's Method Chlorine test and the High Temperature Chlorine test. Both tests showed conclusively that the water within the holds was not seawater.

Tests of the actual moisture contained in the samples resulted as follows:

- the surface sample from number 1 hold, 41 %;
- the sub-surface sample number one hold, 36.5 %;
- the sub-surface sample number five hold, 38.9 %.

To obtain the flow moisture point of the nickel ore sample, SGS used the 'Flow Table' method described in 'appendix D' of the BC Code and then derived the value for TML. This resulted in a TML of 29.2 %. All of the ore samples represented had moisture contents that significantly exceeded the TML determined using the IMO standard flow table test.

Liquefaction of nickel ore

Nickel ore has not been considered to be prone to liquefaction. This cargo is regularly carried with total moisture contents in excess of 36%. On this occasion, however, the cargo in Padang Hawk's 1, 2, 3 and 4 holds had every outward appearance of having suffered 'liquefaction' during the voyage.

Liquefaction (refer to Appendix A) occurs in granular cargoes that are loaded with excessive moisture and subjected to energy from ship motions. There are any number of scientific definitions of liquefaction. The 1997 annual of the American Society for Testing and Materials defines 'spontaneous' liquefaction as:

> …the sudden large decrease of the shearing resistance of a cohesionless soil. It is caused by the collapse of a structure by shock or other type of strain and is associated with a sudden but temporary increase of the prefluid pressure. It involves a temporary transformation of the material into a fluid mass.

In excess of 90 % by weight of the ore loaded by Padang Hawk had a particle size

2 The International Maritime Organization's Code of Safe Practice for Solid Bulk Cargoes (BC Code) defines the TML of a cargo which may liquefy as the maximum moisture content of the material which is considered safe for carriage in ships not complying with the special provisions of 7.2.2 and 7.2.3 (specially fitted or constructed cargo ships). It is derived from the flow moisture point (flow table test appendix D.1) or from data obtained from other test methods approved by the appropriate authority of the port State as being equally reliable.

of less than 1 mm, 82.5 % of the cargo had a particle size of less than 0.053 mm. This cargo was typical of the limonitic nickel ores being mined in New Caledonia. The small relative particle size and chemical properties of the mineral mean the amount of moisture in these nickel ore cargoes can be large without an appreciable change in the appearance or static handling properties. Limonitic nickel ores adsorb any free intergranular water into the mineral structure over a period of time. Adsorption of any free water continues until the ore is 'saturated' and unable to take up any more water. Handling problems may occur when saturated ore is subject to vibration or stress, or if there is a significant amount of unadsorbed intergranular free water.

At some time during voyage number 904, despite the fact that the crew pumped the hold bilges regularly and effectively on 24, 25 and 26 July, a portion of Padang Hawk's nickel ore cargo liquefied and moved to port causing the vessel to list. After listing to port on the evening of 26 July, the crew inspected the cargo holds and observed the cargo flowing with the movement of the ship. On arrival in Townsville the cargo in the forward four holds displayed clear evidence of liquefaction in the fluid form of the cargo and the free water present on the surface of the cargo in number 1 hold. The varying degree of liquefaction of the cargo, with the forward holds being the most affected, may be explained by the motion of the ship in the rough sea. Padang Hawk was pitching and rolling heavily on 25 and 26 July. All of the cargo would have been similarly effected by the rolling. However, the amplitude of the pitching, and thus its effect on the cargo, would have been greater at the forward holds. The cargo in number 1 hold would also have been the most effected by any 'pounding' and this probably accounts for the particularly poor state of the cargo in this hold.

By the time the test 'grabs' were taken from number 1 hold on the morning of 29 July, sufficient free water had been readsorbed by the nickel ore for the cargo to return to a solid state.

The cargo

The shipment of the limonitic nickel ore from New Caledonia to Townsville is subject to a detailed agreement between the cargo sellers (Nickel Mining Corporation) and Queensland Nickel Pty Ltd (QNPL). The agreement specifies the minimum characteristics of the ore and the conditions under which it should be shipped. This agreement includes provision for:

- an agreed maximum moisture content (free water) of 35 %, with a lower refer ence price for ore with a moisture content in excess 36 % and, conversely, a higher reference price for ore with a moisture content less than 34 %;
- a particle size not to exceed 200 mm;
- flow tests prior to loading to demon strate to the satisfaction of the buyer and the ship's master that the shipment will not flow; and
- a statement by the seller acknowledging the master's right to refuse to load the cargo based on the results of the flow tests.

With regard to the flow tests, the agreement requires that:

Ten representative samples from the stockpile to be loaded aboard the ship are to be tested no later than seven (7) days prior to the scheduled arrival of the ship.

All results of flow tests should be recorded, conveyed and delivered to:

(a The Ship's Master (before the commencement of loading):

(b Seller, and

(c Buyer.

The master received details of voyage number 904 from the shipowner's Brisbane representative. For information on the cargo and loading, the master was referred to the detailed instructions provided for voyage number 903. This telex included standard details of the cargo, loading and discharge ports, agents, and advice relating to demurrage. It did not contain any specific details of the moisture limits, density, or other cargo characteristics. Nor did it contain any direction pertaining to the acceptability of the cargo.

The master was not provided with the results of the flow tests or the moisture content of the nickel ore prior to loading the cargo on voyage number 904. There is some doubt that the master knew that this information had to be provided under the terms of the agreement and that he had the right to refuse the cargo based on the results of the flow tests. By failing to provide the master with this information, however, the cargo shippers were not only

FIGURE 8.
Cargo, hold number 3

in breach of the agreement but also the provisions of the International Convention for the Safety of Life at Sea (SOLAS). (See Appendix B).

On 27 July, the day after the incident, the shippers did send the ship a facsimile with a copy of the 'Moisture Certificate' certifying that the ore loaded had a maximum free moisture of 37 %. A second document detailed the results of a series of 10 flow tests carried out between 11 July and 16 July. These are shown in Table 1.

Table 1
Flow test results, New Caledonia

Sample No.	Date of test	Deformation (mm)
1	01/07/99	1.7
2	11/07/99	1.9
3	12/07/99	2.2
4	12/07/99	2.0
5	13/07/99	2.3
6	13/07/99	2.1
7	14/07/99	2.0
8	15/07/99	1.8
9	16/07/99	2.3
10	16/07/99	2.1

These tests showed sample 'deformations' (the degree to which the cargo 'flowed' in the test) of 1.7–2.3 mm. All of the samples indicated that the cargo loaded aboard Padang Hawk in Kouaoua on voyage number 904, was fit for carriage using the QNPL criteria which stipulates a maximum acceptable deformation of 3 mm.

According to information obtained independently on behalf of the Inspector of Marine Accidents by the French Marine Casualties Investigation Board, the moisture content of the ore was 37.4 % which agrees reasonably well with the information provided to the master on the 'Moisture Certificate'. QNPL also provided the investigation with a chemical analysis of the nickel ore cargo shipped by Padang Hawk on voyage number 904, which indicated that the average moisture content was 36.55 %.

Representative samples

The QNPL agreement with the seller stipulates that 10 'representative samples' must be tested 'no later than seven (7) days prior to the scheduled arrival of the vessel'. The wording of this portion of the agreement is somewhat ambiguous. It can be read to mean that the cargo should be tested at least 7 days before it is to be loaded when in fact the final testing should take place just prior to the time of loading.

In the case of Padang Hawk's voyage number 904, according to the flow test records supplied by the shipper after the incident (shown in table 1), 10 tests were in fact performed in the week prior to the ship's arrival at Kouaoua on 17 July. The last tests were conducted the day before on 16 July. Given the subsequent liquefaction of the cargo, the results of these flow tests would indicate that either; the flow test procedure is flawed in some way, or that the samples tested were not representative of the cargo as a whole.

QNPL provided information as to how the samples are collected from the ore stockpiles:

> The method by which the samples are taken will vary according to the type and size of the ore stockpile. The supplier is required to utilise his expertise to obtain a representative sample from the stockpile. Typically, samples are taken from the stockpile at a depth which will ensure that the ore has not been affected by the prevailing either wet or dry climatic conditions and is representative of the material to be loaded. This is normal-

ly done by a small backhoe and depth of sample is approximately 0.5 to 1.0 metre.

Rainfall records for Kouaoua for July 1999 from the Meteorological Office of New Caledonia showed that in the first half of the month of July, Kouaoua had received 171 mm of rain, 105 mm of which was recorded on 14 July, three days before Padang Hawk arrived. At the Kouaoua nickel mine and ship-loading facility, the stockpiles of ore are stored in the open. The cargo intended for Padang Hawk would have been fully exposed to the rain. The flow tests conducted on 14, 15, and 16 July showed sample deformations of between 1.8 and 2.3 mm and thus no significant increase as a result of the heavy rain on 14 July. Nevertheless, the nickel ore loaded aboard Padang Hawk on voyage number 904 was saturated to the point where free water was observed running from the cargo as it was loaded.

The cargo was not fit for carriage in spite of the fact that the records of the sample tests conducted in the week prior to loading failed to indicate any abnormality with the nickel ore.

Flow tests

The standard IMO flow moisture point test is described in appendix D of the BC Code. Part of the test requires that a representative sample of test material is placed in a standard 'mould' and compacted in a prescribed fashion with a standard 'tamper'. The sample, now in the form of a truncated cone, is then turned out of the mould onto a standard 'flow table' and the table is raised and 'dropped' 50 times, from a height of 12.5 mm, at the rate of 25 times per minute. If the sample shows 'plastic deformation' after this process, it indicates that the sample has reached a flow state. If the sample does not show plastic deformation, it is placed in a mixing bowl and a small amount of water is added. It is then returned to the mould, tamped, and retested on the flow table. The whole process is repeated until the sample shows plastic deformation indicating that a flow state has been reached.

The IMO procedure requires that the moisture content of a sample just above the flow point and another just below the flow point are to be ascertained using a standardised drying procedure. An average of these values forms the flow moisture point of the ore. The TML is then calculated and is 90 % of the flow moisture point expressed as a percentage of water by mass.

The agreement between QNPL and the seller states that the standard IMO flow moisture point test procedure is not suitable for limonitic ores. As a result, QNPL have adapted the standard IMO flow moisture point test to form the 'flow test' procedure detailed in their agreement with the seller.

The equipment used, the sample preparation, and the actual methodology of the QNPL 'flow test' are almost the same as those described in the BC Code for the flow moisture point test. The main difference between the two tests is that the simplified QNPL test requires no addition of water. QNPL explained the reasons why the adaptation of the IMO procedure was necessary and these are detailed in Appendix C.

The QNPL-adapted flow test only prescribes a maximum allowable sample deformation of 3 mm and does not stipulate that the actual flow moisture point or the transportable moisture limit must be established.

According to the flow moisture point test in the BC Code, 'plastic deformation' of the sample indicates that a flow state has been reached. The Code does not indicate an 'acceptable' level of deformation. By the definition adopted in the BC Code, all of the samples tested prior to loading the Padang Hawk's voyage number 904 cargo had reached a 'flow state'.

The Japanese experience

Around 4 million tonnes of saprolitic nickel ore is shipped to smelters in Japan each year. There have been a number of reported instances where this cargo has 'shifted', as a result of excessive water content, while being carried from mines in the Philippines, Indonesia and New Caledonia to Japan. After researching marine casualty databases, the ATSB found there had been a recent incident where a ship was lost while carrying nickel ore to Japan.

In August 1998, the Panama flag ship Sea Prospect foundered with the loss of ten seafarers from a crew of 21. The ship had a full cargo of nickel ore loaded in Indonesia and was en route to Hiroshima in Japan. The ship broadcast an SOS signal in a 2 m sea with wind speeds of less than 20 knots. There is no information as to whether the loss of the ship could be attributed to the shift of cargo, the deformation of cargo, or to high moisture levels.

The Japanese authorities have been concerned for some time about the propensity of nickel ore cargoes to shift, and the Journal of the Society of Naval Architects of Japan (vol 187, June 2000) contains a Study on Prevention of Sliding Failure of Nickel Ore in Bulk. The study details a new procedure for evaluating the shear strength of nickel ore and thus the suitability for carriage of the cargo. The test procedure utilises a 'cone penetrometer' to measure the shear strength of a graded sample of nickel ore suitably compacted in a standard container. Advice from Professor Tamaki Ura of the University of Tokyo, one of the authors of the nickel ore study, is that when the moisture content of nickel ore is higher than a critical value, it loses shear strength. The Japanese study refers only to nickel ore and does not differentiate between limonitic and saprolitic ores.

In submission QNPL reiterated:

> QNPL utilises ore from the limonite zone, while the Japanese and New Caledonian smelters utilise saprolite ore, which exhibits different handling characteristics due to its differing mineralogy and particle size distribution. Consequently the comments from Professor Tamaki Ura may not be applicable to limonite, as they almost certainly are related to saprolite.

Stability

The accepted practice on bulk cargo ships is to calculate the vessel's stability prior to departing both loading and discharge ports. Stability calculations are performed using: data relating to the vessel's draft; the quantity and location of known masses including, ballast, fuel, fresh water, etc; and the vessel's stability curves and tables, (usually in tabulated format and often computer based). These calculations are performed, usually by the mate, to ensure the vessel has adequate stability for the planned passage and any contingencies that might be encountered en route. On Padang Hawk, this was not an onerous task as the ship was equipped with a loading/stability computer.

When Padang Hawk completed loading the cargo of nickel ore at Kouaoua on

24 July, no stability calculations were undertaken prior to the vessel departing the port. The master knew from previous experience with the cargo that the vessel had a surplus of stability after loading. Once the cargo had become fluid, and Padang Hawk had developed the 15° list to port, the master's initial response was to pump ballast into 3 and 5 starboard topside tanks. No stability calculations were undertaken prior to this ballasting operation to ensure that the vessel would remain stable. Once again, the master relied on his experience and judgement in correcting the vessel's list without using the hard facts available from the ship's loading/stability computer.

The owners of the vessel were consulted once the list had been corrected using the two topside tanks. Their advice was to transfer the ballast from the topside tanks to the double bottom ballast tanks. The owners expressed concern that the ballast in the topside tanks compromised the vessel's stability. The ballast was subsequently transferred in accordance with the directions of the owners. The most critical times during these operations were the 'transient' conditions when the topside and double bottom tanks were being emptied or filled with a consequent 'free surface'. The vessel's stability was not calculated for any of these operations.

The relevant stability data for Padang Hawk was obtained for the purpose of the investigation. The vessel's stability was calculated independently for the purposes of the report using the departure data from Kouaoua, for an initial condition, and the subsequent conditions of the starboard topside tanks ballasted, and the double bottom tanks ballasted. The calculations showed that the vessel exceeded the intact stability criteria recommended in the 'Code of Intact Stability for all Types of Ships Covered by IMO Instruments (Resolution A.749 (18))'. In using the topside tanks on this occasion the ship was not in fact put at risk through the possible loss of intact stability. The topside tanks do have a higher centre of gravity than the double bottoms, but have much smaller 'free surface' and bigger righting effects.

While recognising the circumstances and the imperative to right the ship's list, the master took a significant risk in ballasting the vessel, by adding weight centred high and outboard with an accompanying free surface, without first checking the likely effect on the vessel's stability. Although the master was correct in his assessment of the stability, there was a risk of far worse consequences for the vessel and crew, should his intuitive judgement have been faulty. It would have been prudent to use the available resources to calculate the stability of the vessel for all of the conditions prior to transferring any ballast.

Conclusions

These conclusions identify the different factors contributing to the incident and should not be read as apportioning blame or liability to any particular organisation or individual.

The factors contributing to the shift of Padang Hawk's nickel ore cargo and the consequent port list include, but are not limited to:

1. The cargo was loaded with excessive moisture content.

2. The vessel was subjected to heavy seas, which led to the cargo changing state from a solid to a viscous liquid in 4 of the 5 holds.

3. Insufficient knowledge of the characteristics of nickel ore as a cargo and its propensity to become fluid when the moisture content is high and it is subjected to sufficient physical stress.

4. There is no test to specifically ascertain the 'transportable moisture limit' of nickel ore.

5. The owners/agent of the vessel did not include in the master's voyage instructions the relevant information pertaining to the cargo moisture content, flow tests, and the master's right to refuse to load the cargo under the terms of the agreement between QNPL and the cargo sellers.

6. The ore seller did not provide the master with the agreed data pertaining to the cargo's moisture content and flow tests as required by SOLAS.

7. The master loaded the nickel ore without insisting on the provision of the data concerning the moisture content and flow tests.

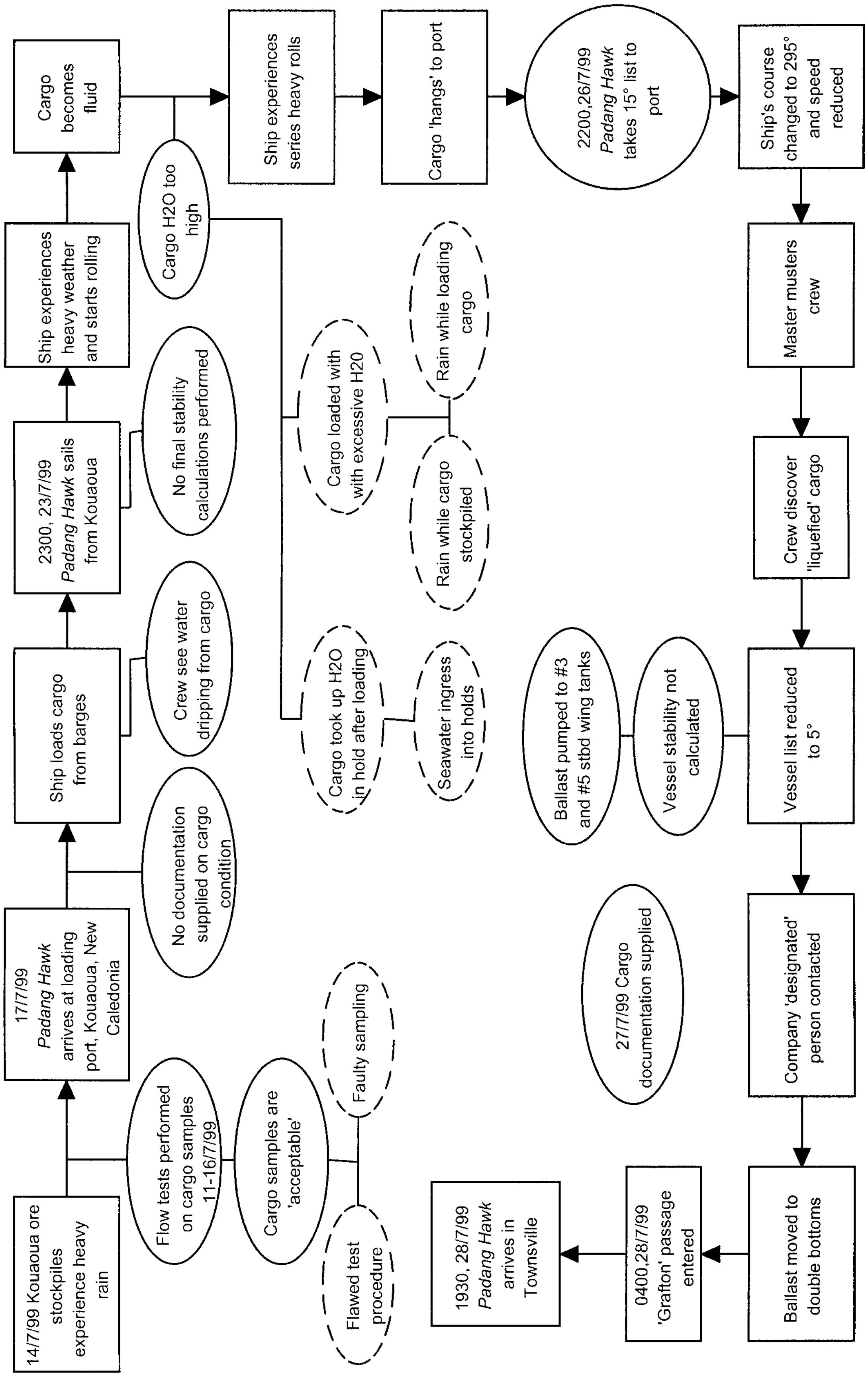
8. The mined nickel ore was stockpiled in areas open to the ingress of rainwater.

9. The agreement between QNPL and the seller did not stipulate a reasonable, maximum, acceptable moisture content, based on the nickel ore's ability to be carried safely by sea.

Also:

10. The vessel's stability should have been calculated for the loaded condition leaving Kouaoua and subsequently checked prior to the pumping of ballast into the topside and double bottom tanks to correct the list.

FIGURE 9.
Padang Hawk events and causal factor chart



Submissions

Under sub-regulation 16(3) of the Navigation (Marine Casualty) Regulations, if a report, or part of a report, relates to a person's affairs to a material extent, the Inspector must, if it is reasonable to do so, give that person a copy of the report or the relevant part of the report. Sub-regulation 16(4) provides that such a person may provide written comments or information relating to the report.

The final draft of the report, or relevant parts thereof, was sent to the following:

The Master, Padang Hawk

Singa Star Pte Ltd

Daiichi Chuo Shipping (Singapore) Pte Ltd

Queensland Nickel Pty Ltd

Nickel Mining Corporation, New Caledonia

Australian Maritime Safety Authority

Professor Tamaki Ura, University of Tokyo

Submissions were received from Queensland Nickel Pty Ltd, the Australian Maritime Safety Authority, and Professor Tamaki Ura. The text of the draft was amended and portions of the submissions included as appropriate.

Details of ship

Name	Padang Hawk
IMO No.	9109354
Flag	Singapore
Classification Society	Nippon Kaiji Kyokai
Vessel type	Bulk carrier
Owner	Singa Star Pte Ltd
Year of build	1995
Builder	Mitsui Engineering and Ship Building, Japan
Gross tonnage	27 011
Summer deadweight	46 635 tonnes
Length overall	189.80 m
Breadth, moulded	31.00 m
Draught (summer)	11.60 m
Engine	Mitsui Man B&W 6S50MC
Engine power	6 532 kW
Service speed	14 knots
Crew	20 (Filipino)

Liquefaction

Granular materials have void spaces between the particles caused by the irregular shape of the particles. These void spaces may be filled with air, water or a combination of both. When a cargo containing moisture is subjected to energy such as ship motions, the cargo particles move to compress the void spaces and pressurise any free water present in the spaces (pore water pressure). In addition, moisture may be released from the mineral structure of some types of cargo when subjected to ship's motions. This release of adsorbed water increases the amount of free water in the cargo and leads to a further increase in the pore water pressure. If the pore water pressure becomes high enough, it overcomes the friction forces binding the individual particles of material and the shear strength of the cargo falls to the point where liquefaction occurs. The cargo becomes a viscous fluid with the ability to flow.

The BC Code provides guidance to administrations, shipowners, shippers and masters on the standards to be applied in the safe stowage and shipment of solid bulk cargoes, excluding grain. There is a specific section on cargoes liable to liquefaction and an appendix, appendix A, which contains a list of such cargoes.

Nickel ore is not contained in the appendix.

However, the introduction to the Code specifically states:

> … it should be carefully noted that the list of materials appearing in appendices A,B and C to the Code is by no means exhaustive and the physical properties attributed to them are intended only for guidance. Consequently before loading any bulk cargo it is essential to ascertain – normally from the shipper – the current physical characteristics and chemical properties of the material.

The Code notes the characteristics of such cargoes as one that:

> …generally consist of a mixture of small particles as contrasted with natural ores which include a considerable percentage of large particles or lumps.

SOLAS

The International Convention for the Safety of Life at Sea, regulation 2, part A, chapter VI, 'Cargo Information' states:

1 The shipper shall provide the master or his representative with appropriate information on the cargo sufficiently in advance of loading to enable the precautions which may be necessary for proper stowage and safe carriage of the cargo to be put into effect. Such information shall be confirmed in writing and by appropriate shipping documents prior to loading the cargo on the ship.

And further:

2 The cargo information shall include:

.2 in the case of bulk cargo, information on the stowage factor of the cargo, the trimming procedures and, in the case of a concentrate or other cargo which may liquefy, additional information in the form of a certificate on the moisture content of the cargo and its transportable moisture limit.

The adapted flow test procedure

The flow test procedure used to test the nickel ore carried by Padang Hawk on voyage number 904 is outlined in the agreement between the cargo seller and QNPL. The flow test is adapted from the BC Code procedure for ascertaining flow moisture point and, like the Code, it identifies that:

> …a flow state is considered to have been reached when the moisture content and compaction of the sample produces a level of saturation such that plastic deformation occurs. At this stage, the moulded sides of the sample may deform, giving a convex or concave profile.

The agreement goes on to set a limit on the 'acceptable' amount of sample deformation:

> Under plastic deformation, if the increase in the diameter of the moulded sample measured at any part of the cone exceeds 3 mm, the cargo which it represents is considered unsuitable for shipment.

QNPL provided the following explanation as to why the BC Code procedure is not suitable for testing limonitic ores:

> The IMO Test was developed for concentrates which have no specific structure and involves mixing of water with the material. In the case of limonitic nickel ore, this test changes the structure of the macro particles and the test material becomes a different material to the product being transported, therefore it is not suitable for use in testing the suitability for transport of limonitic nickel ore.

Specifically relating to the ore structure, QNPL said that:

> …the sample preparation of limonite nickel ore for the flow moisture test, and the act of adding water to this sample, increases the amount of free water present as opposed to adsorbed or absorbed water.
>
> There are two main reasons for this:
>
> Firstly most of the water in an undisturbed piece of limonite is adsorbed onto the very high surface area possessed by the very fine grained (to almost amorphous) goethite dominated mineralogy. This is why undisturbed pieces of limonite containing >40% moisture can appear dry. Water entering a piece of limonite will probably take much more time than a flow moisture test would allow to change from being intergranular free water to becoming water adsorbed onto the goethite minerals. Unlike adsorbed water, free water moves amongst the pieces of limonite and lubricates them allowing them to move freely, leading to slumping or collapse.
>
> Secondly and perhaps most importantly, the above effect is compounded when:
>
> - preparation of the sample for the flow moisture test disturbs the material. This disturbance (which is greater than any mining and loading operation does to ore) leads to compaction or slicking of limonite pieces (1mm-10cm range), thus reducing the permeability of the surface of these pieces,
> - then added water cannot be absorbed into the pieces and runs or slurries as free water amongst the surfaces of the grains.
>
> The stability coefficient of a limonite sample is probably more dependent on the amount of free water than on the amount of adsorbed water, so for example:
>
> - sample A with 40% absorbed water and 0% free water is much more stable than:
> - sample B with 30% absorbed water and 10% free water.
>
> All of this is independent of the effect of liquefaction caused when adsorbed or absorbed water is released from near saturated limonite by vibration.

In 1986, QNPL commissioned a study of the behaviour of limonitic nickel ore during shipping. Gutteridge Haskins & Davey and Chalmers University, Gothenburg, carried out tests specifically related to the likely behaviour of nickel ore to evaluate ship unloaders. The investigations were related to the determination of the shear strength of nickel ore, density and stability of ships cargoes under the conditions encountered at sea. A further report by Gutteridge Haskins & Davey in 1990 titled Gag Island Nickel Laterite Deposit Report on Ship Stability, Trial Shipments V3/90 and V4/90 concluded in part that 'no significant strength changes have been observed within Gag Island limonite or saprolite as a result of shipment'. These reports form the basis of QNPL's third-party verification of their adapted flow test.