SUPPRESSED

UNTIL

1.00am ON Thursday 28 May 2009

"Confidentiality order: This report is subject to a suppression order prohibiting disclosure of the report and its contents until public release at 1.00am on Thursday 28 May Prohibited disclosure is an offence"

Report 07-207, bulk carrier, *Taharoa Express*, cargo shift and severe list, 42 nautical miles southwest of Cape Egmont, 22 June 2007

CONFIDENTIALITY ORDERS

Pursuant to sections 11 and 14B(2)(d) of the Transport Accident Investigation Commission Act 1990, section 4 of the Commissions of Inquiry Act 1908, and Section 42 of the District Court Act 1947, the Commission has made orders suppressing this report and its contents, and prohibiting the disclosure of the report and the information contained in the report until the date and time of public release as identified on the cover of this report. The report has been provided to certain persons in advance of public release on a confidential basis, and on the basis that further disclosure of the report and its contents is prohibited. Any act of disclosure in breach of these requirements is an offence under s14L of the Transport Accident Investigation Commission Act 1990.

Any inquiries as to the terms and effect of the confidentiality orders that have been made should be addressed to the Commission.

The Transport Accident Investigation Commission is an independent Crown entity established to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future. Accordingly it is inappropriate that reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

Report 07-207

bulk carrier
Taharoa Express

cargo shift and severe list

42 nautical miles southwest of Cape Egmont

22 June 2007

The *Taharoa Express* at anchor in Tasman Bay

Photograph courtesy of Hachiuma Steamship Company Limited

The *Taharoa Express* loading at Port Taharoa single buoy mooring

Contents

Figures

Abbreviations

º	degree
ALARP	as low as reasonably practicable
bulk code	Code of Safe Practice for Solid Bulk Cargoes
bulk loading code	Code of Practice for the Safe Loading and Unloading of Bulk Carriers
Class NK	Nippon Kaiji Kyokai
DMT	dry metric tonne(s)
ESP	enhanced survey programme
Fr	frame
GM	a broad measure of the stability of a ship
GZ	a righting lever that returns a ship to upright when heeled by an external force
IACS	International Association of Classification Societies
IMO	International Maritime Organization
ISM	international safety management
ISM Code	International Management Code for the Safe Operation of Ships and for Pollution Prevention
km	kilometre(s)
kW	kilowatt(s)
m	metre(s)
m3	cubic metre(s)
Maritime NZ	Maritime New Zealand
MetService	Metrological Service of New Zealand
mm	millimetre(s)
MSC	Maritime Safety Committee
MOU	Memorandum of Understanding
NKK	Nippon Kohan K.K
nm	nautical mile(s)
NS* (Bulk Carrier) (ESP)MNS	ship constructed to Class NK Rules, ship type, ship applies enhanced survey programme for bulk carriers and tankers, main propulsion machinery built to Class NK rules
NYK	Nippon Yusen Kaisha
NZ Steel Mining	New Zealand Steel Mining
NZST	New Zealand standard time
port safety code	New Zealand Port and Harbour Marine Safety Code
SOLAS	International Convention for the Safety of Life at Sea
TML	transportable moisture limit
UK	United Kingdom
UTC	co-ordinated universal time
VHF	very high frequency

Glossary

ballast system	series of compartments within a ship designed to take water for adjusting the draught, trim, list and stability of the ship
cape-size bulk carrier	a bulk carrier with dimensions larger than those allowable to transit the Panama Canal
close-up inspection	an inspection where the surveyor is to be within arm's length of the area under scrutiny
coaming	vertical erections around hatches and other openings in a deck, to prevent water passing into the opening
cope hole	a hole cut into steel plate to provide access for welding
corrugated bulkhead	corrugated steel partition between adjacent cargo holds on a bulk carrier
deadweight	total weight, in tonnes, of cargo, stores and fuel carried on board by a ship at its maximum permitted draught
de-canting	the removal of supernatant water on top of iron sand within a ship's holds
de-watering	the physical removal of water from iron sand within the ship's holds by filtration
down flooding	the entry of seawater through any opening into the hull or superstructure of an undamaged vessel
draught	depth in water at which a ship floats
duct keel	twin girders with space between them. Increases longitudinal strength and allows bilge and ballast piping to lie in the space and be readily accessible
earth fault	leakage of electrical current to a ship's hull, commonly caused by a degradation of insulation or water ingress in electrical circuits
eductor	a hydraulic device used to create a negative pressure (suction) by forcing a liquid through a restriction, such as a venture
Environment Waikato	the prevailing local council for the Waikato region at the time of the incident. Unless specifically stated, "Environment Waikato" has been used to represent the local authority of the day
frame	rigid profile providing strength to the hull of a ship
gross tonnage	a measure of the internal capacity of a ship; enclosed spaces are measured in cubic metres and the tonnage derived by formula
harbour	defined in the New Zealand Port and Harbour Marine Safety Code 2004 as: including the waters and any port within any pilotage area defined in Part 90 of the Maritime Rules, and any other coastal or inland waters that a regional council determines are a harbour for the purpose of this code in accordance with a code application assessment
heel	transverse inclination of a ship owing to external forces such as wind pressure and wave action
iron sand slurry	iron sand and fresh water mixed in equal proportion by weight
knot	one nautical mile per hour
liquefaction (bulk cargo)	liquefaction occurs where under the motion of a ship, water within the cargo causes a loss of cohesive strength between the particles of the cargo, resulting in all or part of the cargo flowing like a liquid
list	transverse inclination of a ship owing to the disposition of internal weights
lower stool	support at the bottom of a transverse corrugated bulkhead providing a shedder surface for cargo to slip down when unloading
Maritime New Zealand	unless specifically stated, "Maritime New Zealand" (Maritime NZ) has been used to represent the maritime authority of the day

messenger line	a relatively light rope used to haul in a heavier one
mimic diagram	a means of displaying the status of a system
port	defined in the New Zealand Port and Harbour Marine Safety Code 2004 as: a coastal marine area within a harbour occupied by a port company pursuant to a coastal permit issued under section 384A of the Resource Management Act 1991, or pursuant to any other right of occupation, and includes any berth or channel that is agreed by the regional council and the port company to be the responsibility of the port company
roadstead	anchorage and manoeuvring area for vessels off a port
scantling draught	the maximum draught that meets strength requirements
single buoy mooring	a single floating chamber (buoy) moored offshore where ships can dock and load or unload their cargo. Cargo is transported to the buoy from ashore through a submerged pipeline
supernatant water	the liquid lying above iron sand after the sand has settled out of the slurry to the bottom of a hold
stability	the ability of a vessel to return to the upright when heeled
strum box	metal box with perforated circular holes in its sides, fitted to the end of a suction pipe to prevent the entry of material that may block the pipe or pump
trim	difference between fore and aft draughts of a ship
trimming	levelling of cargo within a cargo space, either partial or total
tripping brackets	reinforcements in the form of flat bars or plates on deck girders’ beams or stiffeners to prevent their free flanges being deformed under compression

Data Summary

Ship particulars:

Name:	*Taharoa Express*
Type:	specialised titanomagnetic concentrate carrier
Class:	Class NK (Nippon Kaiji Kyokai)
Limits:	SOLAS ship
Classification:	NS*(Bulk Carrier)(ESP)/MNS
Length:	269.53 metres (m)
Moulded beam:	43 m
Gross tonnage: Deadweight tonnage:	74 364 145 842
Built:	1990, Ulsan, South Korea
Propulsion:	one direct-drive reversible crosshead diesel engine: Hyundai B&W 5S70MC Maximum Continues Rating (MCR): 11,466kw at 78 revolutions per minute through a fixed-pitch, 4-bladed, 8.2 m diameter propeller
Service speed:	14 knots
Owner/Operator:	Arafura Shipping Inc./Hachiuma Steamship Company Limited, Japan
Port of registry:	Panama
Crew:	23

Date and time:	22 June 2007 at about 0200[1]
Location:	42 nautical miles southwest of Cape Egmont
Persons on board:	crew: 23 pilots: 2
Injuries:	crew: nil pilots: nil
Damage:	minor to moderate damage to ship structure
Investigator-in-charge:	Paul Bird

[1] Times in this report are New Zealand Standard Time (UTC + 12 hours) and are expressed in the 24-hour mode.

Executive Summary

At about 1330 on 21 June 2007, the specialised bulk iron sand carrier *Taharoa Express* left its single buoy mooring in Port Taharoa to seek refuge in Tasman Bay from forecast severe weather.

The ship had been scheduled to have a slurry of about 116 000 dry tonnes of iron sand mixed with water pumped aboard. Earlier during the loading process the ship's duct keel had flooded with water from the slurry-loading process, disabling the ship's ballast and cargo de-watering systems. The water had gravitated from the cargo overflow recesses into the duct keel through welding access holes left unsealed after steel renewal in dry dock prior to the loading voyage. When the *Taharoa Express* departed Port Taharoa it had an estimated 17 800 cubic metres (m^3)of water on top of the iron sand that had settled in 5 of its cargo holds, as well as number 6 water ballast hold and several ballast tanks being partially full. The ship initially had a 1.5 degree (˚) starboard list when it sailed.

During the voyage to Tasman Bay, the starboard list progressively increased, unnoticed by key personnel on board until about 0150 on 22 June when the ship took a larger roll that woke key personnel, who found that the ship had a 17º starboard list. The *Taharoa Express* was manoeuvred for the remainder of the trip to Tasman Bay to minimise the motion of the ship in the heavy seas, but the list reached 22º before the ship reached the shelter of Tasman Bay.

The cause of the list was the progressive shift of iron sand in all loaded holds owing to wash action caused by sloshing free water, and possibly contributed to by an en masse shift of iron sand in one or more cargo holds.

Before the *Taharoa Express* reached the shelter of Tasman Bay it was losing stability reserves and at significant risk of capsize owing to the shifting cargo and the free water in the cargo holds. The ship was also at growing risk of suffering structural failure owing to a combination of the increasing list, the distribution of cargo against the side shell plating, and the sloshing forces against the structure.

Mandatory safety management systems for the ship operator and for aboard the ship, and a voluntary safety management system for the management of loading and for the operation of the port were all partially or poorly developed and applied by the 3 different organisations responsible, and they did not integrate with each other sufficiently. This meant that the potential for the incident circumstances to arise and be managed had not been realised or planned for. A hierarchal, rigid and compartmentalised culture within the ship's crew and its management company resulted in communication difficulties that meant that early warnings of the failing systems were misdiagnosed or ignored.

None of the organisations responsible had a clear understanding of the cargo sand's properties generally. The onboard stability computer could not adequately analyse the ship's stability characteristics for a specific load. International and New Zealand standards for carrying bulk cargoes and general regulatory requirements for safety management and oversight were unmet.

A range of safety recommendations to the Director of Maritime Safety and the ship's Flag State of Panama ask for the deficiencies identified in the report to be addressed.

(Note: this executive summary condenses content to highlight key points to readers and does so in simpler English and with less technical precision than the remainder of the report to ensure its accessibility to a non-expert reader. Expert readers should refer to and rely on the body of the full report.)

Investigation Timeline and Process

On Friday 22 June 2007, the Rescue Coordination Centre of New Zealand notified the Transport Accident Investigation Commission (the Commission) of an incident involving the bulk carrier *Taharoa Express* off the Taranaki coast of New Zealand. The ship had a 17º starboard list and was approximately 42 nautical miles (nm) southwest of Cape Egmont in heavy weather, making for shelter in Tasman Bay. The Commission immediately launched an investigation and monitored the progress of the ship as it sought shelter.

On 22 June 2007, the Commission notified the authorities in Panama of the incident involving a ship under their register, as recommended under the International Maritime Organization (IMO) Casualty Investigation Code. No response was received from them.

On 23 June 2007, 2 investigators from the Commission travelled to Tasman Bay and boarded the ship at its anchorage to gather evidence for the inquiry.

The *Taharoa Express* remained at anchor for the following 15 days while the free water was removed from on top of the cargo, the cargo was re-trimmed level and various repairs were made to the satisfaction of the Classification Society and the Port State Maritime New Zealand (Maritime NZ).

On 8 July 2007, with all Class and Maritime NZ conditions having been met, the ship sailed for Port Taharoa to complete loading.

On 9 July 2007, investigators from the Commission visited the ship during loading at Taharoa to continue their investigation and to familiarise themselves with the port and loading operations.

On 17 October 2007, during a subsequent voyage, the *Taharoa Express* again sailed to Tasman Bay to seek shelter from adverse weather. Following reports of damage that may have been related to the incident voyage, investigators from the Commission again boarded the ship in Tasman Bay to make an assessment of the new information.

The Commission seconded a naval architect from Maritime NZ to assist in the investigation, and engaged an independent marine consultant based in the United Kingdom (UK) to assess the effect of sloshing forces on the ship's structure, and to determine to what extent the cargo shift and free water on board affected the ship's stability.

Reports submitted by New Zealand Steel Mining (NZ Steel Mining) on post-incident experiments to determine the mechanism for cargo shift were considered, together with other independent opinions from experts in cargo liquefaction.

A draft preliminary report was considered by the Commission on 20 November 2008, and the preliminary report was approved and sent to 25 interested persons for comment. Eight written submissions were subsequently received and reviewed, with further oral submissions invited and received by the Commission on one.

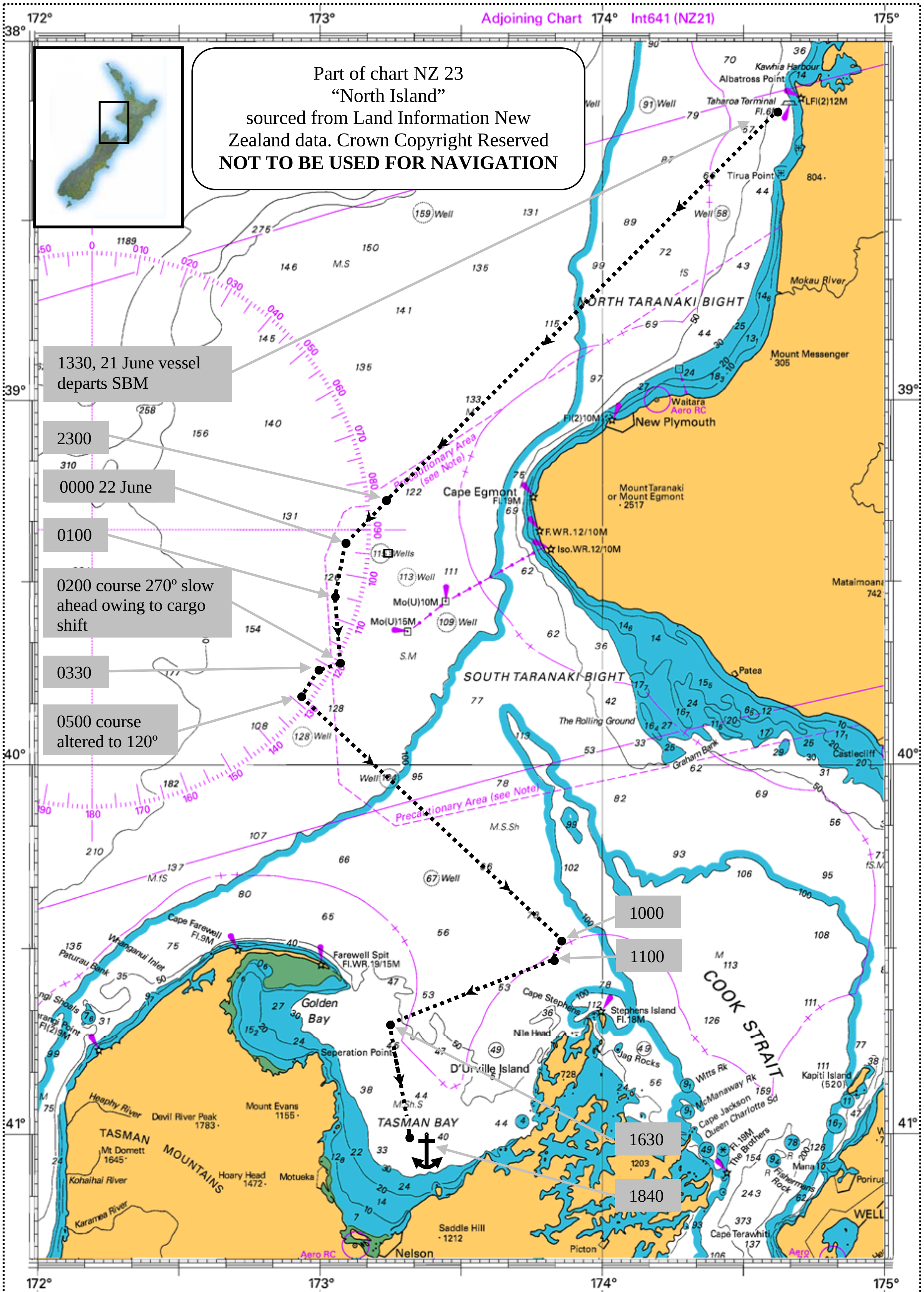


Figure 1
Chart of the general area showing the ship’s passage from Port Taharoa to Tasman Bay

1 Factual Information

1.1 Narrative

1.1.1 On Saturday 2 June 2007, the bulk carrier *Taharoa Express*, having just completed a 45-day lay-up for surveys and repairs, departed the port of Zhoushan in China for Taharoa to load a cargo of iron sand.

1.1.2 The day after departing Zhoushan, the duct keel bilge alarm activated and the water inside was removed using the bilge eductor. The next day the duct keel alarm activated again and the first mate investigated the cause. He found seawater ballast from number 6 cargo hold leaking through a crack in a welded seam of the forward lower stool, which had just been repaired in Zhoushan.

1.1.3 Because the leakage rate was manageable, it was decided not to attempt a repair until after the ship had loaded at Taharoa, when number 6 cargo hold would be empty. The first mate pumped the duct keel daily using the bilge eductor, starting it at about 0900 and stopping it at about 1500. The duct keel bilge alarm activated most days on the voyage to Taharoa.

1.1.4 At about 1100 on Monday 18 June 2007, the ship arrived off Taharoa. The pilot and trainee pilot, who also acted as loadmaster and trainee loadmaster respectively, boarded the vessel using a helicopter. They were accompanied by a superintendent from the ship management company, who was there to complete an international safety management (ISM) audit while the ship was in Taharoa. At about 1155, the ship was moored to the single buoy mooring located about 1.6 nm off the shore.

1.1.5 About 116 000 dry metric tonnes of iron sand were expected to be loaded on the ship in alternate holds over the next 54 hours. The iron sand was to be pumped on board as slurry through 2 lines from the terminal ashore, via the buoy then floating hoses to the ship. A pipe system on deck distributed the slurry to the required hold.

1.1.6 Once the slurry was in the hold, the sand settled to the bottom while supernatant water was removed from above it using onboard de-canting and de-watering processes. After all the slurry had been loaded, a further 24 hours were allowed for de-canting and de-watering of the cargo before the ship sailed. When the ship arrived at the discharge port, the cargo was unloaded using a conventional crane and grab.

1.1.7 The weather forecast was initially good, but was expected to begin to deteriorate on Thursday 21 June, about 3 days later (see Appendix 7).

1.1.8 On 18 June at about 1255, 2 floating hoses from the mooring buoy were connected to the ship. There was a short delay before loading started owing to an air compressor problem ashore. Slurry loading started at about 1410, filling number 3 cargo hold via number 1 line, and number 7 hold via number 2 line (see Appendix 1).

1.1.9 At about 1600, the first mate started de-ballasting to maintain a suitable trim and keep the stresses on the hull within the limits set out in the agreed load plan. This plan included de-ballasting 18 665 tonnes of seawater from number 6 cargo hold.

1.1.10 At about 1815, a problem with number 2 load line was reported by the shore terminal; the line was flushed through with water and isolated for repairs at about 1840.

1.1.11 Continued filling of number 3 hold on number 1 line only would have reduced the stern trim of the ship, so to prevent this happening the first mate changed number 1 line to load into number 7 hold. At about 2045, de-ballasting of number 6 cargo hold was stopped to keep the trim and hull stresses within acceptable limits.

1.1.12 On Tuesday 19 June at about 0040, number 2 load line was operational again and loading reverted to the original plan, number 1 line loading to number 3 hold and number 2 line loading to number 7 hold.

1.1.13 At about 0500 the duct keel bilge alarm activated in the engine room. The duty engineer accepted the alarm but did not relay this information to the first mate who normally pumped the bilge.

1.1.14 At about 0500, the first load to numbers 3 and 7 holds was complete. There was another interruption in loading on both lines because of another air compressor problem ashore. Loading resumed at about 0715 with both load lines filling number 5 hold, the next on the load plan.

1.1.15 At about 0800 a 220-volt earth fault alarm was activated in the engine room. The alarm was not considered high priority so no immediate investigation was undertaken to find the cause.

1.1.16 At about 0845, a leaking pump gland on a slurry pump ashore caused another delay on number 2 line. Loading number 5 hold continued on number 1 line.

1.1.17 At about 0900, the first mate in the cargo control room noticed that the indicator light for one of the number 5 hold overflow recess suction valves on the slurry control console was not working and that he could not operate the valve. He informed the chief engineer, who on investigating found 3 electrical circuit breakers had tripped. At about 0915 the chief engineer suggested the cause might be water in the duct keel where the valve controls were located. At about 1000, a crewman was sent to check the duct keel. He reported to the first mate that the aft duct keel contained 2 m of water. The first officer started pumping the water from the duct keel using the bilge eductor.

1.1.18 At about 1105, after consultation between the master, first mate and company superintendent, the trainee loadmaster was requested to switch number 1 line to load number 1 hold, while a problem with number 5 hold was fixed. At about 1120, number 2 line had been repaired and it was used to load number 9 hold. Numbers 1 and 9 holds were next in the planned load sequence.

1.1.19 The ship's officers wanted to stop loading number 5 hold because they could not operate the de-canting and de-watering valves in that hold. Arrangements were made to take regular soundings of the water level in the duct keel, which remained at about 2 m for several hours. The superintendent tried for some time to contact the company head office in Japan to advise it of the situation and seek advice.

1.1.20 The crew initially thought that the amount of water leaking from the crack in the forward lower stool of number 6 hold had increased. At about 1300, the superintendent tried to enter the duct keel through the mid access between numbers 5 and 6 holds but the water level was too high to make an inspection. At about this time all ballast operations ceased owing to a malfunction of the majority of the remote-operated valves in the duct keel.

1.1.21 Loading of numbers 1 and 9 holds continued. At 1700 a sounding of the duct keel was taken, which showed the water level was about 3.7 m; subsequent soundings showed the water level was still rising. The height of the duct keel was 2.4 m, which meant that the aft part of the duct keel was completely full of water, which was now also filling up the aft access trunk.

1.1.22 Further discussion took place over the flooding of the duct keel. The loadmaster, who was now aware of the extent of flooding in the duct keel, suggested to the master that loading be stopped. The master agreed in principle, but he and the superintendent on board decided to seek the advice of the head office in Japan before they suspended operations.

1.1.23 At about1900, on advice from the ship management company office in Japan, loading was stopped. The aft duct keel sounding was about 5 m, and the access manhole door in the pump room was secured in case the water level rose further and overflowed into the pump room. Some water was, however, leaking through an electrical cable gland in the pump room floor from the flooded duct keel below; this was handled easily by using the engine room bilge system.

1.1.24 At about 1930, water issued from the aft sounding pipe for the duct keel when it was opened, indicating the aft duct keel access was now full. In an effort to increase the pumping rate, a larger-capacity bilge pump was used on the bilge main, but it made no improvement. Concern was raised as to whether there was a problem with the section of bilge line inside the duct keel. This turned out to be correct. The chief engineer later inspected the end of the bilge suction pipe in the duct keel and found the strum box had been incorrectly fitted. The exposed end of the pipe was partially blocked by a plastic cap about 80 millimetres (mm) in diameter. The cap had been originally fitted to the electro-hydraulic valve control gear in the duct keel.

1.1.25 The ship had a stern trim of about 0.40 m at this time. The emergency fire pump room situated in the lower stool space between numbers 5 and 6 holds was also flooded at this time, indicating the duct keel was completely full of water further forward.

1.1.26 At about 0325 on Wednesday 20 June, the level in the aft access trunk to the duct keel had receded to about 5 m and remained about the same for the next 8 hours.

1.1.27 At about 0800, the chief engineer organised the engine room staff to prepare additional means to pump the duct keel. At about 1130, the access manhole to the duct keel in the pump room was opened and additional hoses for pumping utilised. After the introduction of the additional hoses, the level in the duct keel began to decrease at a faster rate.

1.1.28 Pumping of the duct keel continued through Wednesday 20 June. On Wednesday a Maritime NZ inspector from New Plymouth visited the ship to report on the situation to the harbourmaster in Wellington and Maritime NZ. He decided that the duct keel would not be accessible that day, so he returned to New Plymouth with the intention of returning the next day.

1.1.29 On Thursday morning the prevailing wind was still offshore and the conditions on the buoy were within limits; the wind was still forecast to strengthen and back northwest, then west putting the ship onto a lee shore. The pilot suggested to the master that the ship leave the buoy and make for shelter in Tasman Bay, particularly as they expected the weather to be bad for a few days. After consultation with the superintendent and the ship management company in Japan, the decision was made to sail to Tasman Bay.

1.1.30 At this time the aft duct keel sounding was about 2.8 m and the vessel had a starboard list of about 1.5º owing to cargo and/or ballast disposition.

1.1.31 At about 1330 on Thursday 21 June, the ship left the mooring and set a course of 225º across the North Taranaki Bight at full speed, about 12 knots. The pilot and trainee pilot by mutual agreement of the master remained on board the ship for the voyage to Tasman Bay. The weather was recorded as being cloudy with a westerly wind of about 30 knots (see Figure 1).

1.1.32 On departure from Taharoa, the ship's ballast and de-watering systems were still inoperable. Number 6 cargo hold contained about 11 500 tonnes of ballast water and 8 of the ballast tanks were partially full. There was supernatant water on top of the iron sand in all 5 of the ship's partially loaded cargo holds. The total amount of supernatant water on board in the cargo holds was estimated to be about 18 665 tonnes. The cause of the flooding of the duct keel had still not been identified.

1.1.33 At about 1500, a sounding taken of the aft duct keel was about 2.6 m. The first mate and superintendent entered the forward duct keel entrance to locate the source of the water ingress. They noticed that water was still entering the duct keel from the lower stools between numbers 1 and 2 cargo holds and numbers 3 and 4 cargo holds. They found water leaking in through unsealed cope holes in numbers 1 and 3 overflow recesses where steel repairs had been carried out in Zhoushan.

1.1.34 The crack in the forward lower stool of number 6 ballast hold was leaking water at a similar rate to that noted on the voyage to Taharoa. They were not able to inspect further aft owing to the high water level in that part of the duct keel.

1.1.35 Most of the ship's staff, including the master and pilots, had dinner then retired to their cabins for the evening.

1.1.36 At about 2300, the third mate, who was officer of the watch, altered the ship's course to 210º as it passed about 30 nm off Cape Egmont. The wind was reported as west-south-west and gale force (35-40 knots) and the ship's speed was about 9 knots; the alteration put the sea and swell on the starboard bow.

1.1.37 At midnight the third mate was relieved by the second mate. The second mate estimated that the ship's list was about 15º to starboard, whereas the third mate estimated it to be about 5º. Neither of them reported the increase in the list to the master.

1.1.38 The bridge log noted that at about 0100 the second mate altered the ship's course to 166º. The ship's position and course logged in the global positioning system receiver log book do not support this being the actual course steered, which was about 180º. The wind direction was recorded westerly at gale force.

1.1.39 At about 0155, the ship took what was reported to be a violent roll, which woke the pilot. Concerned at what he thought was a large list and the unusual motion of the ship, the pilot made his way to the bridge.

1.1.40 When the pilot arrived on the bridge, he found only the second mate and the look-out. The pilot suggested to the second mate that he alter the ship's course to 270º and reduce the engine from full ahead to slow ahead. The second mate wanted to telephone the master, but the pilot more strongly reinforced his view that the course and speed alteration should be effected immediately. The second mate then carried out the pilot's request before calling the master to advise him of the situation.

1.1.41 The master and superintendent arrived on the bridge a short time later and, after a discussion with the pilot, the pilot called Farewell Maritime Radio using very high frequency (VHF) radio on channel 16. He advised it that the ship had a 15º list from suspected cargo movement, the ship was stemming the swell and they did not require immediate assistance. A radio schedule was then agreed and maintained.

1.1.42 At about 0300, the pilot advised Farewell Maritime Radio that they were still heading 270º making about 2 knots and the list had stabilised at 17º. After discussion between the master, superintendent and pilot it was decided to try to find shelter as originally planned. The weather forecast was for the wind to increase and change to the southwest. By about 0430, the ship's heading was about 230º and the engine speed was increased to half ahead.

1.1.43 At about 0500, the ship's speed was increased to full ahead and the course altered to 120º. The wind was on the starboard quarter and the ship was heading for shelter behind D'Urville and Stephens Islands. After the turn was complete the list had increased to 19º.

1.1.44 By about 1030, the decision was made to head into Tasman Bay. As a precautionary measure, in case the situation deteriorated as the ship altered course and went beam on to the weather, the crew (apart from essential engine room personnel) were assembled on the bridge. The wind was recorded as westerly 45 knots gusting 50, with a westerly swell of about 5 m.

1.1.45 At about 1100, the course was altered to 255º to head towards Golden Bay and the lee of Farewell Spit. After the course alteration the starboard list increased to 21º. The ship's speed was reduced to slow ahead.

1.1.46 At about 1210, the list was recorded to have increased to 22º. The decision was made to try to reduce the list by transferring ballast by gravitating water from number 6 cargo hold to number 3 port ballast tank. This required the first mate assisted by some of the crew to enter the duct keel and use a portable hydraulic pump to open the required ballast valves. The ballast transfer was not successful, most likely because of the large list. At about 1425 ballast was pumped into number 3 port water ballast tank and the list began to reduce.

1.1.47 At about 1630, the ship began to receive some shelter from Farewell Spit and the ship's course was altered to 165º towards Tasman Bay. At 1840 the ship anchored in Tasman Bay about 18 nm north of Nelson. The ship had a starboard list of about 19º and ballast operations were suspended.

1.2 Post-Incident survey and inspection

Tasman Bay, 23 June-8 July 2007

1.2.1 On Saturday 23 June, 2 investigators from the Commission travelled to Tasman Bay and boarded the ship.

1.2.2 On Sunday 24 June, a Maritime NZ maritime safety inspector boarded the ship to complete a statutory inspection on behalf of the Port State, New Zealand. He was accompanied by a Class NK surveyor who was there at the request of the ship management company to ensure the statutory requirements of the Classification Society and the Flag State, Panama were met.

1.2.3 On 24 June the Class NK surveyor had completed his inspection and required the following repairs to be completed at anchorage in Tasman Bay, set out in survey record 07AU0324:

> temporary repairs at Fr. 146, 196 and 246
> [overflow recess numbers 1 and 3, lower stool between 6 and 7 holds]
>
> repair of duct keel valves and indicators
>
> temporary portable emergency fire pump to be supplied until ship's emergency fire pump and access lighting permanently repaired
>
> The repairs are to be completed and re-inspected before departure this port or Port of refuge in New Zealand, by 23 July 2007.

1.2.4 The removal of free water on top of the cargo was expedited using salvage pumps before the cargo could be levelled using bulldozers flown to the ship and lowered into the hold. The ship was returned to an even keel on 1 July but an imbalance in the ballast tanks remained.

1.2.5 On 4 July, the Director of Maritime NZ issued a notice of imposition on the ship. The ship was to remain in Tasman Bay until the cargo had been levelled so that, when on an even keel, the imbalance of ballast water between the port and starboard ballast tanks was less than 2000 tonnes with the hull stresses within limits. All of the conditions imposed by Class NK were also to have been satisfied.

1.2.6 At Tasman Bay water was observed leaking into the hold through a crack in number 4 port ballast tank (see Figure 4). Damage was noted to the number 6 hold vent louvers in the sides of the hatch covers. The damage was consistent with that expected from sloshing water in the hold being forced out through the vent openings under pressure. Distortion to the steel plates in the top of the hatch cover was also noted. When the hold was finally emptied of ballast water, large amounts of scale dislodged from the hold sides were removed from the hold bottom (see Figures 2, 3 and 4).

1.2.7 On 2 July 2 investigators returned to the ship in Tasman Bay. During an inspection of the number 1 hold overflow recess, weld defects were noted where one of a number of additional free-water valves had been fitted. These defects were pointed out to one of the officers on board. The insert plate around the valve had not been back-gouged and welded from the inside of the overflow recess (see Figure 3).

Figure 2
Damage to vents in number 6 hold and scale removed

1.2.8 This would have produced a joint of reduced strength and may have led to the crack propagation from the toes of the incomplete welds. The failure of this plate during loading could have allowed iron sand to enter the recess from the hold and block the outlet and prevent supernatant water being removed by de-canting.

1.2.9 A number of cracks had been found in number 4 ballast tank and the hopper side at the site of previous repairs carried out in Zhoushan in May 2007 (area A in Figure 4). Cracks were also found in number 4 top-side ballast tank (area B in Figure 4). Some of the damage was in an area identified in the subsequent sloshing analysis as being highly loaded on the voyage to Tasman Bay when number 6 hold was only partially full.

1.2.10 On 8 July the temporary repairs had been completed to the satisfaction of the Class NK surveyor and the remote hydraulic valves in the duct keel repaired. Class survey record 07AU0329 set out Class NK requirements for repairs to be completed at the next available port after the discharge of cargo:

permanent repair of previous temporary repairs at Fr. 146, 196 and 246

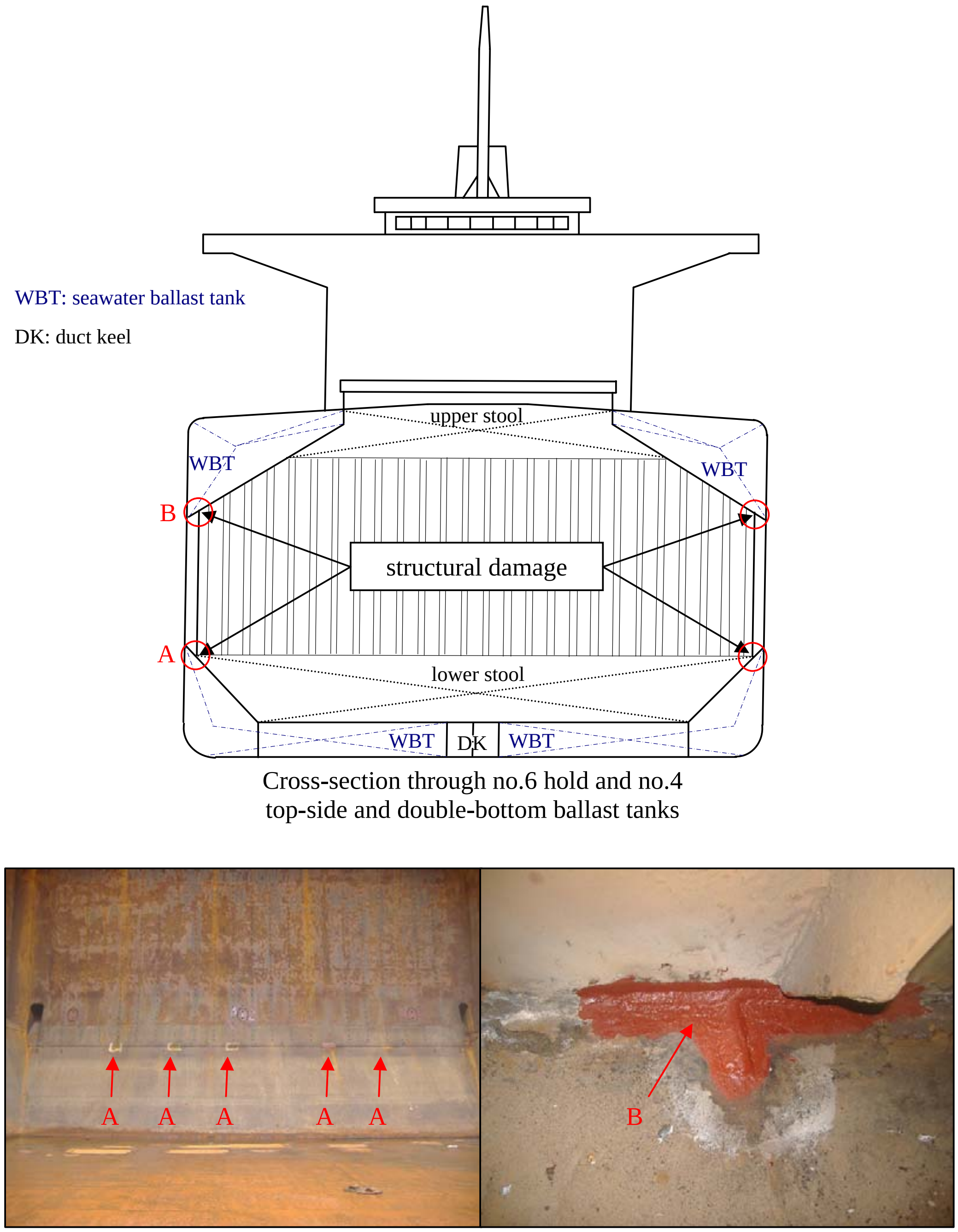
inspection and test of bilge wells and bilge pumping systems for cargo holds

close -up inspection of all previous dry-dock repairs in way of holds.

Figure 3
Deformed plates in hatch lid and insert in number 1 overflow recess

1.2.11 On 8 July the conditions imposed by Maritime NZ had been satisfied and the ship was allowed to sail back to Taharoa to complete loading.

1.2.12 On 11 July loading was complete and the ship sailed to Qinhuangdao in China.



(A) damage at hopper side

(B) repair inside no.4 top-side tank

Figure 4
Structural damage to number 6 hold and number 4 ballast tank

Qinhuangdao, China, 2 August 2007

1.2.13 By 2 August 2007 the required permanent repairs had been completed. As a result of the close-up inspection of the repairs completed in Zhoushan, the following additional work was required:

- defects found in the welding in the forward lower stool in number 4 cargo hold were welded
- tripping brackets were fitted on the side shell plates in the connecting trunk on both sides between frames (Fr) 193 and 194 in number 4 cargo hold.

1.2.14 The ship management company advised that repairs in number 6 ballast hold and the number 4 top-side ballast tank were completed in September. Class NK was not present at the time of the repairs but pressure testing of all the ballast tanks was completed in December with a Class NK surveyor present.

1.3 Ship information

1.3.1 The keel of the *Taharoa Express* was laid on 10 April 1990 by Hyundai Heavy Industries Company Limited in Ulsan, South Korea. The ship was originally designed as a single-hull bulk carrier and named the *Stellar Cape* when it was launched on 23 August 1990.

1.3.2 The original design had 9 cargo holds situated forward of the engine room and accommodation. The ship had a seawater ballast capacity of 42 482 m^3 in its designated ballast tanks and in addition number 6 cargo hold could be used for ballast; it had a capacity of 18 393 m^3. The ship had a heavy fuel capacity of 4284 m^3 and diesel capacity of 222 m^3.

1.3.3 The ship was originally classified as being specially strengthened for heavy cargoes for alternate loading in cargo holds 1, 3, 5, 7 and 9. The ship could also carry cargo in all holds if required when homogenous loading.

1.3.4 For ballast voyages where no cargo was carried, number 6 hold was filled with seawater to keep the stresses in the hull within acceptable limits. When used for ballast, it had to be full to avoid structural design criteria being exceeded by sloshing forces from free water. Number 4 hold could be partially filled up to 55% of the hold volume with seawater for ballast if required when the ship was loading in port. Only number 6 hold was sufficiently strengthened to carry water ballast at sea.

1.3.5 In 1999 the *Stellar Cape* was converted to a slurry loaded iron sand carrier by Nippon Kohan K.K (NKK) at its Tsurumi works in Kangawa Pref., Japan. The conversion work took 2½ months and the ship was delivered to its new owner, Arafura Shipping, on 3 April 1999, and renamed the *Taharoa Express*. The ship was converted specifically to replace 2 smaller ships that had been transporting iron sand from the mine at Taharoa to the Far East.

1.3.6 At the time of the incident the ship was chartered by NZ Steel Mining from its beneficial owner[3] Nippon Yusen Kaisha (NYK), and had been managed since February 2002 by Hachiuma Steamship Company Limited, a company in which NYK held a 70% interest. At the time of the incident the ship was registered in Panama and in survey with Class NK.

1.3.7 A summary of the work carried out at the conversion of the ship for slurry cargo is given below:

- numbers 1, 3, 5, 7 and 9 holds that were to carry iron sand cargo were converted to a double-skin construction to increase the ship's longitudinal strength against shearing force
- numbers 2 and 8 cargo holds were converted to a partial double-skin construction also to increase longitudinal strength. A double-skin was fitted to the existing vertical shell frames and extended only part of the way along the length of the hold. Number 4 hold construction remained single hull at the side shell

[3] As beneficial owner NYK actually owned the ship even though the title was in another name.

- number 6 hold was also converted to a double-skin, which extended the whole length of the hold. Subsequently, cut-away sections were made in the inner side skin in the corners of the hold for stress relief
- overflow recesses and valves were fitted to the aft transverse corrugated bulkheads in the iron sand cargo holds 1, 3, 5, 7 and 9. Bilge trunks and de-watering filters were fitted in iron sand cargo holds
- a pump room was constructed within number 9 cargo hold with access from the engine room. Pumps for removing free water via the overflow recesses, and pumps for removing the water via the de-watering system, were located in this pump room
- slurry load lines were fitted to the upper deck of the ship
- pipelines from the overflow recesses to the pump room were installed
- a bilge main and valves were installed for de-watering of cargo holds through the duct keel
- a hose handling crane and mooring bollard were fitted on the forecastle.

1.3.8 At the request of NYK the plans and documents for the conversion were submitted by the designer (NKK) to the classification society, Class NK. Some of them were approved under the relevant Class rules and others were received for reference.

1.3.9 The fitting of the double-skin in number 1 hold allowed Class NK to exempt the ship from the requirement of being able to withstand total flooding of the foremost hold required under the International Convention for the Safety of Life at Sea[4] (SOLAS) Chapter XII for existing single-skin bulk carriers. The global structure of the ship was such that some holds were of only partial double-skin construction. All the other applicable requirements of Chapter XII to a bulk carrier of single-skin construction commensurate with its age had been applied at the time of the incident.

1.3.10 Calculations were carried out to assess the strength of the existing structure and modifications made for the new cargo arrangement. These calculations considered 2 separate conditions: the ship at sea and the ship slurry loading in port. Class NK advised that it did not require the designer to consider sloshing forces that free water imparts on the hull structures in the cargo holds in determining the hold scantlings because the conversion plans were approved on the assumption that the ship should proceed to sea after the supernatant water had been removed and the moisture content was less than the transportable moisture limit (TML).

1.3.11 Class NK applied 1999 rules for alternate loading, which was based on the extra strength given to the ship at conversion and the reduced volume of the holds owing to the double-skin construction.

1.3.12 A separate finite element analysis was then completed using direct calculations to evaluate the strength of the middle holds and the longitudinal strength of the ship, which Class NK advised was to evaluate the new structure with the ship loaded and on passage. The analysis of the internal pressures in the cargo holds did not include dynamic pressures from moveable water, because it was assumed there was no free water in the holds. Wave loads acting on the outside of the ship were included and evaluated with the hull in the trough and peak of a wave at the scantling draught. As a result of the analysis, additional stiffening by doubling was fitted to the duct keel. Following the modifications, the analysis concluded that the hull mid structure had sufficient strength.

1.3.13 Strength calculations in a separate report considered the relative levels of the iron sand and supernatant water at various stages of the loading process. This report then used this data to calculate, for each of the various stages of loading, the static water pressure and the sloshing pressure on the transverse bulkhead and side shell owing to the supernatant water. When Class

[4] See section 1.15 for further details.

NK approved the conversion in 1999 it advised that it did not have exact information on the loading operation in Taharoa.

1.3.14 The sloshing calculations used a maximum GM of 5.16 m and the external conditions applied took into account the natural period of rolling of the ship. Thus the external conditions applied took account of the rolling motion of the ship only and made no account of any specific sea states or other motions to which the ship could be subjected at the single buoy mooring.

1.3.15 Class NK also said it assumed that the ship would be loaded and unloaded according to the Code of Safe Practice for Solid Bulk Cargoes (bulk code) and SOLAS regulations. To verify the strength of the ship, Class NK took into account some of the specific properties of the Taharoa iron sand. Design strength calculations quoted a sailing moisture content of the sand of 11.1% at departure based on full load draught condition. The calculations did not consider the moisture content of the sand with respect to any requirements of the bulk code and a potential for cargo shift.

1.4 Slurry loading

Port of Taharoa

1.4.1 Taharoa was located on the west coast of the North Island of New Zealand about 80 nm northeast of Cape Egmont. When loading, the ship was secured to a single buoy mooring that was anchored in approximately 30 m of water about 1.6 nm offshore. The prevalent weather was westerly onto a lee shore. A wave rider buoy was located about 500 m northeast of the mooring and provided real-time wind and swell data to the ship and the terminal ashore (see Figure 5).

1.4.2 A helicopter was used to embark the harbour pilot who conned the ship to the buoy without tug assistance. The harbour pilot remained on board in his capacity as loadmaster, leaving the ship once he had conned the ship off the buoy for de-watering.

1.4.3 A 26 m long support vessel, the *Margaret J*, handled the messenger lines for the hawser and the floating loading hoses at the buoy. The *Margaret J* was also used for single buoy mooring maintenance and provided standby services for the helicopter that remained stationed at Taharoa whilst the ship was in port. The *Margaret J* was based in Kawhia Harbour (about 4 nm east-north-east of Albatross Point) and owned by NZ Steel Mining; it was managed by Marine Mooring Consultants Limited.

Load method

1.4.4 The bulk density of the iron sand was the mass of the sand divided by the volume it occupied. The normal bulk density of the sand exported from Taharoa was 2.737. Iron sand was loaded as a slurry on a one-to-one ratio by weight with fresh water, which meant that for every cubic metre of sand, 2.737 m^3 of water were mixed with it to make the slurry. 2500 tonnes per hour of slurry were pumped through each of the 2 separate load lines; the same load method had been used since mining began in 1972.

1.4.5 The ship was not designed to carry iron sand as slurry at sea, so water had to be removed from the holds as the ship was loaded. This ensured that the structural strength and stability of the ship were not compromised and maximised the lifting capacity of the ship. Removal of the supernatant water was completed in 2 stages: de-canting and de-watering, described later in this section.

1.4.6 Once the supernatant water above the cargo had been removed by de-canting and de-watering, the de-watering process removed water from the saturated sand. This process continued on passage and relatively dry iron sand was left, which was unloaded by conventional grab and crane.

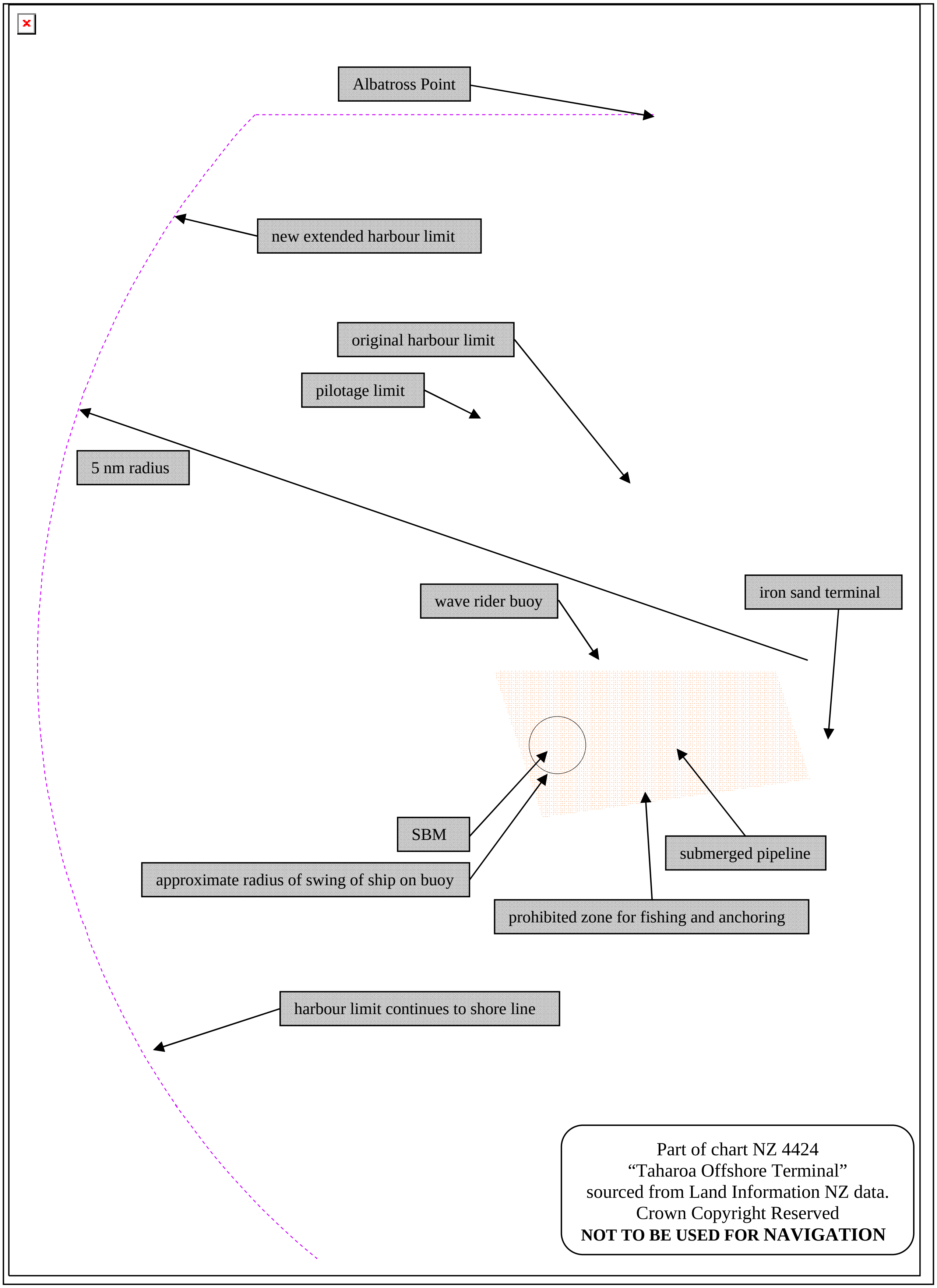


Figure 5
Chart of Taharoa Offshore Terminal

1.4.7 In each of 2 identical loading systems ashore, iron sand from the stockpiles at the terminal was bulldozed into hoppers onto a moving conveyor. The sand was then fed to another conveyor on which it was weighed. This was called the shore scale reading and was used to give those on board a quick and reasonable estimation of the weight of the dry iron sand loaded. After weighing, the iron sand was fed into a constant density tank where it was mixed with fresh water to form slurry (see Figure 6).

1.4.8 From the tank, 6 centrifugal pumps arranged in series pumped the slurry through approximately 3 kilometres of pipe to the pipeline end manifold on the seabed. Flexible hoses or risers connected the manifold to the buoy. Floating hose strings then connected each load line from the buoy to a manifold on the ship's weather deck. The floating hoses and the mooring line for the ship were connected to a rotating cradle on the buoy, which allowed the ship and hoses to swing around it under the influence of the swell, wind and tide.

1.4.9 From the manifold, a system of pipes and valves directed the slurry to the cargo holds through 2 pipelines. Number 1 pipeline was connected to numbers 1, 3 and 5 cargo holds and number 2 pipeline to numbers 5, 7 and 9 holds. Bypass valves allowed the 2 deck pipelines to be interconnected. The status of the valves (open or shut) was displayed on the slurry console in the cargo control room located in the ship's accommodation (see Figure 11).

1.4.10 Slurry entered the hold through a moveable nozzle, which was operated manually by the ship's crew. This allowed the sand to be distributed in the cargo hold so as to keep the ship upright during loading. To assist de-watering, the iron sand surface needed ideally to be even athwartships and sloping downwards towards the aft bulkhead of the hold. This also trimmed the cargo so it was less prone to sliding.

1.4.11 Before iron sand could be loaded, it was necessary to pre-fill the hold with water to cover the de-watering filters in the bottom of the hold to prevent impact damage from the high-velocity iron sand granules in the slurry. The slurry was then loaded into each hold in 2 or more stages to keep the stresses on the ship's hull within limits.

1.4.12 Although it was theoretically possible to load more than 2 cargo holds at a time through a single pipeline from ashore, it was not the practice because the sand particles could settle out of the slurry and block the pipeline owing to the reduced velocity of the slurry in the pipeline.

1.4.13 Once in the cargo hold, the iron sand settled quickly from the slurry to the bottom of the hold. Above the sand was a zone where the iron sand was still settling from the water, and on top of this another zone of supernatant water. Once the loading stopped, this zone of clear supernatant, or "free", water extended down to the iron sand surface.

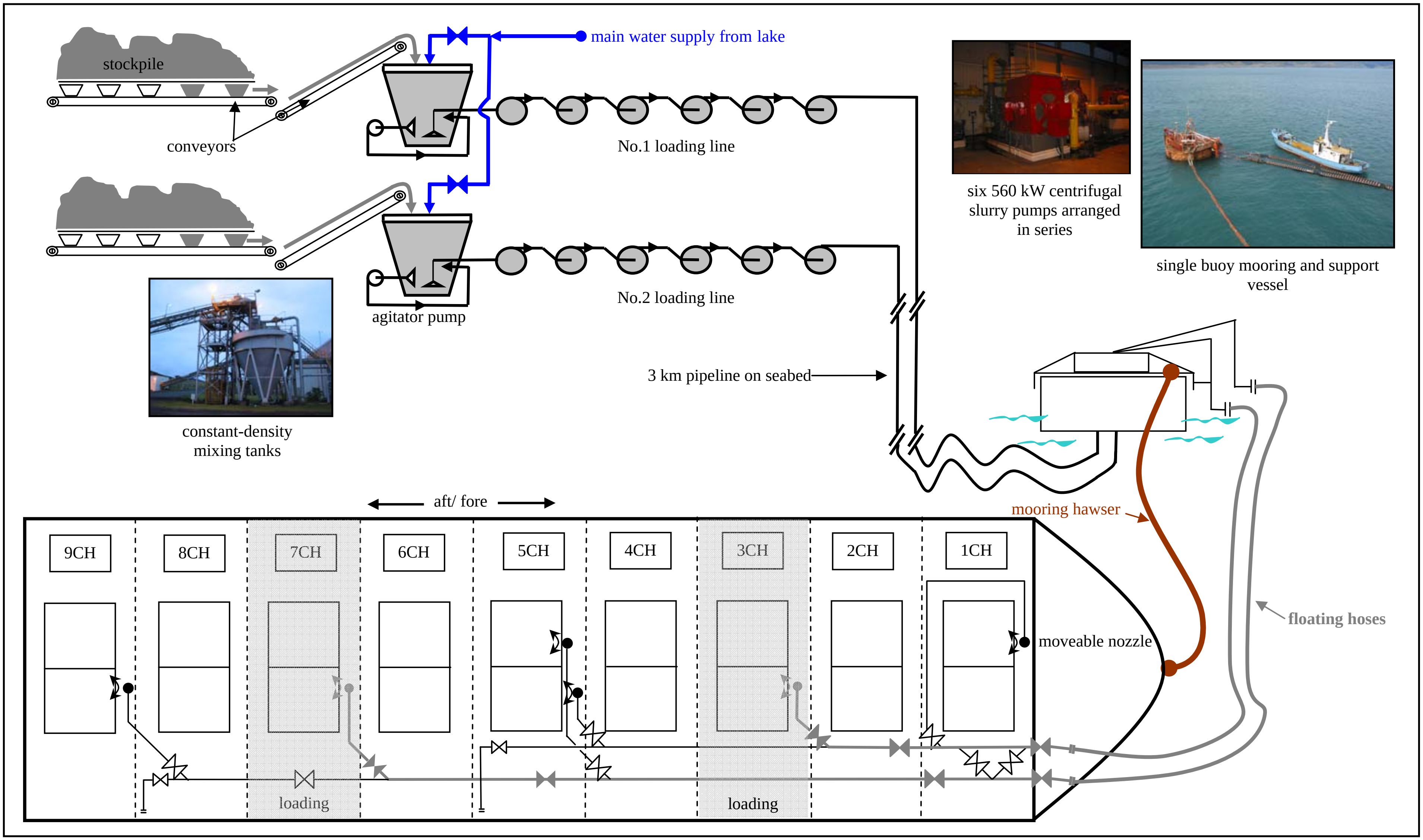


Figure 6
Simplified diagram of slurry loading from shore to ship

De-canting process

1.4.14 Figure 7a is a longitudinal cross-section through a cargo hold and shows the de-canting arrangement. In the aft corrugated bulkhead of each cargo-carrying hold was an overflow recess that extended across approximately one-third of the width of the ship and down into the lower stool space below the corrugated bulkhead.

1.4.15 Typically each overflow recess was connected to the hold by two 250 mm diameter emergency valves, operated hydraulically using a hand wheel on the weather deck. Three 300 mm diameter free-water valves located above the emergency valves were operated electro-hydraulically from the cargo office. Above the free-water valves was an overflow channel containing openings in the corrugated bulkhead that allowed water to overflow into the overflow recess.

1.4.16 Figure 7a shows the approximate level in the hold after filling with water to cover the de-watering filters before slurry loading. The normal practice for this stage was for the emergency valves to be closed to prevent iron sand getting into the overflow recess. The free-water valves higher up were left open. The flow capacity of the free-water valves was such that the water level still reached the overflow channel. Water is removed by de-canting and de-watering.

1.4.17 Figure 7b shows the approximate level of iron sand after the first stage had been completed. As the sand settled out of the slurry it took approximately 7 hours' loading in numbers 3, 5 and 7 holds through a single pipeline for the water level above the settled sand to reach the overflow channel. In the smaller holds, numbers 1 and 9, this time was reduced to about 5 hours.

1.4.18 The water in the overflow recess was pumped overboard through the overflow system. The overflow system consisted of two 450 mm diameter pipe mains in the duct keel that could be cross-connected to either of 2 overflow pumps in the pump room. With the exception of number 5 hold, which had a valve fitted to each pipe main, each hold had a single remotely operated electro-hydraulic valve connected to one of the pipe mains. These valves were located in the lower stool adjacent to the overflow recess.

1.4.19 Each overflow pump had a capacity of 2000 m^3 per hour and a smaller-capacity bilge pump could also be connected to the system. Float-level switches operated lamps on the slurry console, which indicated when overflow started and gave a rough guide to the water level in the overflow recess.

1.4.20 According to the loading instructions, the main function of the emergency valves was to allow the removal of free water where incomplete loading had taken place. Also, opening the emergency valves when the first load was complete avoided a possible accumulation of fine clay settling on top of the iron sand; this clay was residue of the refining process.

1.4.21 Figure 7c shows the removal of free water from above the sand; through the free-water valves, de-watering was carried out.

1.4.22 Figure 7d shows the second stage of loading underway. The emergency and free-water valves were all shut; water overflowed through the overflow channel and was pumped overboard.

1.4.23 Figure 7e shows the completion of loading. Removal of the water on top of the iron sand was carried out by opening any free-water discharge valves not covered by the iron sand.

1.4.24 The quantity of iron sand loaded was monitored using the shore scale weight and by taking regular soundings through ports in the top of the hold. Tables were then used to convert the soundings to tonnes. This gave a more accurate indication of the amount of iron sand loaded, the level of iron sand relative to the free-water valves and its distribution within the hold.

1.4.25 Once the free water on top of the iron sand had been removed, water trapped within the sand was removed, known as de-watering.

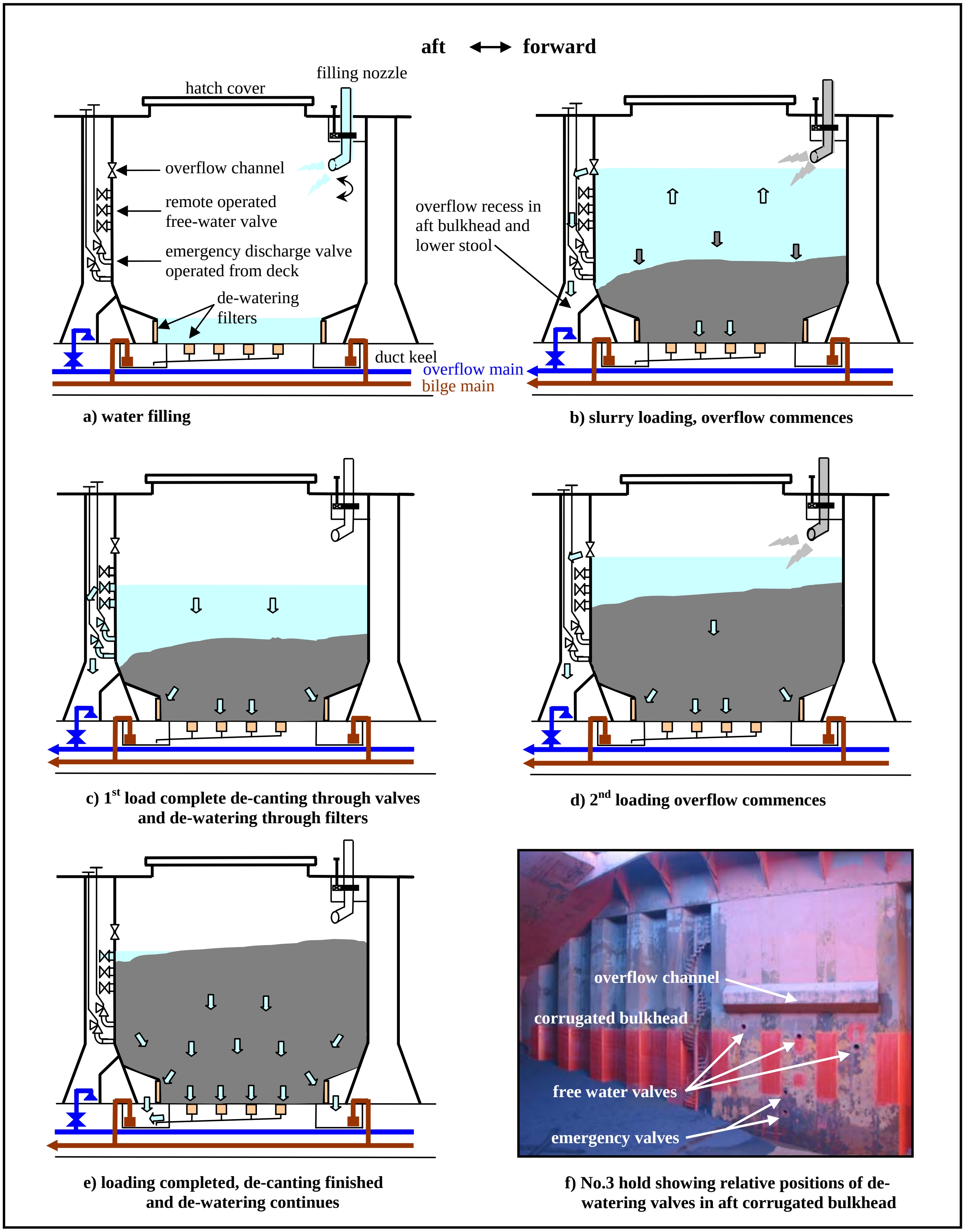


Figure 7
De-canting and de-watering process cargo hold arrangement

De-watering process

1.4.26 Figures 7c and 7e also show the de-watering process, whereby water trapped within the sand was removed. After the supernatant or free water was removed, water between the sand particles permeated to the bottom of the hold. Each cargo hold contained a set of stainless steel mesh filters fitted athwartships across the forward and aft ends. These filters prevented the passage of iron sand but allowed water through into ducts that drained into sealed bilge wells in each corner of the cargo hold. Two sets of cylindrical filters made of an identical mesh in the floor of the hold also drained into the aft bilge wells.

1.4.27 Each bilge well had a high- and low-level alarm and was pumped out using the ship's bilge pump or bilge eductor. The electro-hydraulic bilge valves were located in the lower stools and operated remotely from the slurry console.

1.4.28 The de-watering process continued in port after loading had been completed and on passage to the discharge port. The rate of removal of the water would slow as more water was removed from the sand. The design specification of the ship stated that initially up to 70 m³ per hour per hold could be expected to drain through the sand. After the removal of the free water, the water content of iron sand was about 13.5%. By the time the ship reached the discharge port it had reduced to about 3%.

1.4.29 Figure 8 is derived from data provided by Class NK from when the ship was converted to load slurry cargo in 1999. Similar graphs were produced for each hold to calculate the static pressure acting on the bulkheads owing to iron sand and water at the various stages of loading.

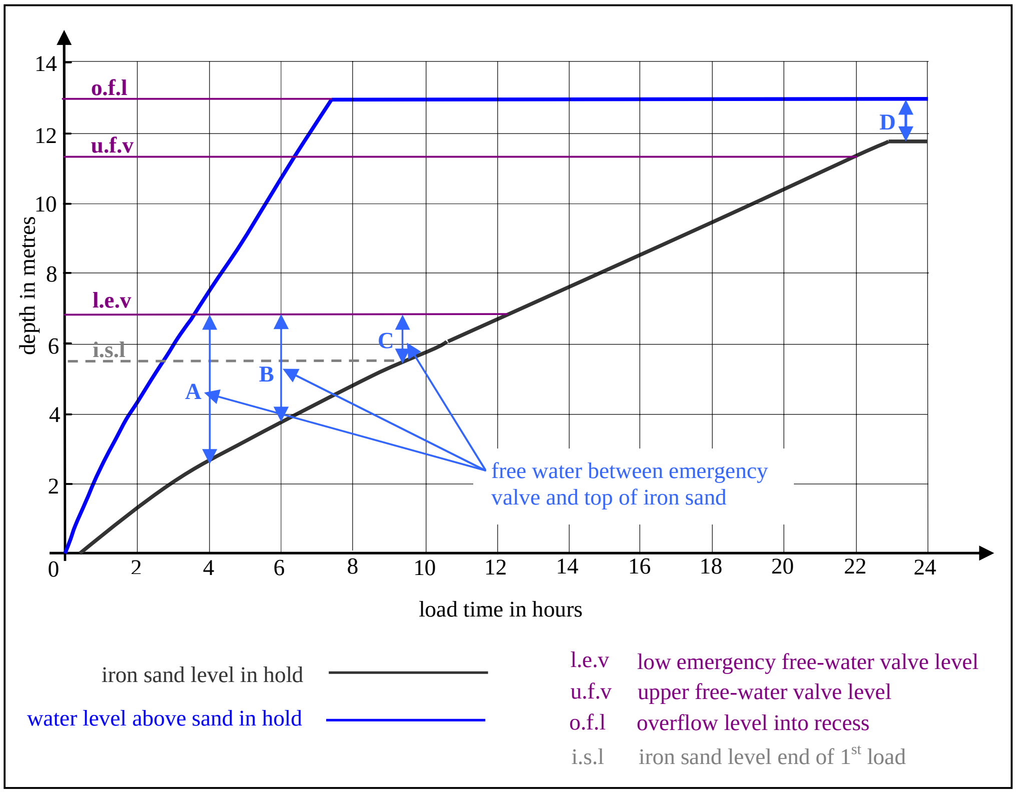


Figure 8
Relative levels of iron sand and water when loading, number 3 hold

1.4.30 For simplicity, only the heights above the bottom of the hold of the lower emergency valve, highest free-water valves and overflow channel are shown.

1.4.31 Figure 8 indicates 3 points in the first loading of 12 000 dry metric tonnes (DMT) of iron sand into number 3 hold. The arrows represent the amount of free water that would be trapped between the lowest emergency free-water valve and the top of the iron sand as follows:

- A: loading stopped after about 4 hours
- B: loading stopped after about 6 hours
- C: at completion of loading 12 000 DMT of sand.

In Figure 8, "D" represents the free water remaining between the overflow recess and iron sand when loading has been completed, assuming a full load of 28 000 DMT.

1.4.32 Below are the calculated volumes of water represented by A, B, C and D in Figure 8 and the approximate time required to remove residual free water on top of the sand by de-watering through the sand at the design rate of 70 m^3 per hour per hold:

- A: 3883 m^3 55½ hours
- B: 2609 m^3 42½ hours
- C: 1208 m^3 17¼ hours
- D: 1276 m^3 18¼ hours.

The calculations assume the ship is on an even trim. A stern trim will reduce the free water quantity because the overflow recess is in the aft bulkhead and cargo is trimmed by the stern.

1.4.33 NKK produced a 72-page instruction manual on the loading of the ship at Taharoa. This manual included a load plan that spanned 64 hours and specified de-watering in each hold at the end of loading after free water had been removed. This was based on the draught and design strength of the ship.

1.4.34 The NKK manual also made reference to:

- past records of sea state during berthing at the port of up to 4 m and rolling up to 25º
- the emergency valves and their use to remove supernatant water overboard for the safety of the ship in case of trouble with the loading facilities ashore or any sudden bad weather from a ship stability perspective.

1.4.35 Under the ship's ISM system, separate manuals were produced covering the operational procedures at Taharoa and for slurry loading.

1.4.36 At the time of the incident, issue 6 of the operation procedures at Taharoa and issue 4 of the loading procedures were in use. Neither manual contained procedures to be followed in the event of a failure of the shipboard de-canting or de-watering plant.

1.5 Loading draught

1.5.1 Near the end of the loading sequence, it was normal practice for the ship to exceed its maximum sailing draught, which was specified in the IMO's International Convention on Load Lines 1966. Having loaded over her marks, de-canting and de-watering continued at anchor within the port limits, until sufficient water had been removed to achieve sailing draught.

1.5.2 The original maximum draught for the *Taharoa Express* was 17.40 m. The ship was certified by its classification society to load over draught in port to 17.71 m, which was the ship's scantling draught. The classification society stated on the certificate that at 17.71 m the ship was in safe limits from a strength point of view.

1.5.3 On 1 July 2006, IMO regulation 14 of SOLAS Chapter XII – Bulk Carriers came into force. The regulation was introduced in recognition of the loads placed on the structure of ageing bulk carriers from loading high-density cargoes in alternate holds. The regulation placed restrictions on sailing with any hold empty as set out below:

> Bulk carriers of 150 m in length and upwards of single-side skin construction, carrying cargoes having a density of 1,780 kg/m^3 and above, if not meeting the requirements for withstanding flooding of any one cargo hold as specified in regulation 5.1 and the Standards and criteria for side structures of bulk carriers of single-side skin construction, adopted by the Organization by resolution MSC.168(79), as may be amended by the Organization, provided that such amendments are adopted, brought into force and take effect in accordance with the provisions of article VIII of the present Convention concerning the amendment procedures applicable to the Annex other than chapter I, shall not sail with any hold loaded to less than 10% of the hold's maximum allowable cargo weight when in the full load condition, after reaching 10 years of age. The applicable full load condition for this regulation is a load equal to or greater than 90% of the ship's deadweight at the relevant assigned freeboard.

1.5.4 Regulation 14 applied to the *Taharoa Express* because of its age, length, single-skin construction and cargo density. Because the *Taharoa Express* was not equipped to load slurry in 4 of its 9 holds, it was not possible for the ship to meet the regulation if it was loaded to 90% or more of the ship's total allowable deadweight.

1.5.5 When regulation 14 came into force, the ship's maximum permitted sailing draught was reduced to 16.0 m and a new load line certificate issued. While technically the 17.71 m scantling draught in port was still permitted under Class rules, both NZ Steel Mining and Maritime NZ recognised that Taharoa was not a safe haven. If there were a sudden change in the weather and the ship had to leave the harbour limits loaded deeper than its maximum draught, the safety of the ship could be compromised.

1.5.6 It was not economically viable to modify the ship; the only option was to reduce the total amount of cargo carried to 89.99% of what the ship was originally designed to carry. It was decided to spread the 10% reduction between numbers 1 and 9 holds to best suit the loading sequence.

1.5.7 SOLAS Chapter XII requirements were brought into effect in New Zealand law through Maritime Rule Part 40B.16 on 17 January 2001. Maritime NZ recognised that under the Local Government Act 1974 section 650C(3) the harbourmaster could be liable if the ship left port in an over-draught condition and suffered damage. Also Class NK had adopted the SOLAS requirements into its own rules governing existing bulk carriers, so they applied to the ship.

1.5.8 On 13 October 2006, the harbourmaster issued a directive stating that the ship was not to exceed 16.0 m draught at any time during loading at Taharoa. This decision was based on the view that Taharoa was not a safe haven and the ship may have to leave at short notice owing to environmental conditions. It was also contrary to the previous practice that had been allowed at the port whereby the ship exceeded its marks during loading.

1.5.9 During the first loading of the *Taharoa Express* under the imposed draught restrictions, a considerable time was spent removing water and loading intermittent decreasing quantities of cargo in order not to exceed 16.0 m draught during the loading process. The ship eventually sailed 3000 tonnes light of its maximum load because the 84-hour lay time it was allocated to load under the charter agreement had been reached.

1.5.10 In response to the directive, NZ Steel Mining submitted a safety case to the harbourmaster to allow the ship to load up to 16.7 m draught provided the weather conditions were favourable. The safety case noted that the ship was potentially at more risk having to spend longer on the single buoy mooring to comply with the new directive.

1.5.11 On 23 February 2006, Class NK reissued a certificate that from a scantling draught perspective allowed the *Taharoa Express* to load over-draught at the harbour condition. The certificate stated that the ship had, at the request of Hachiuma Steamship Company Limited, been examined from a strength perspective to load over-draught by 0.3 m to 17.71 m at Taharoa and found satisfactory.

1.5.12 The harbourmaster did not issue any new directive, but instead NZ Steel Mining invariably requested to load the ship to 17.4 m when loading. These requests were usually granted following a review of the forecast weather by the harbourmaster.

1.6 Loading and ballast plan

1.6.1 The *Taharoa Express* was engaged in a one-way trade, so voyages from the Far East to Taharoa were ballast voyages. To maintain a suitable draught and trim and to keep bending stresses in the hull to a minimum, all ballast tanks were filled with seawater, as was number 6 cargo hold.

1.6.2 When loading started, de-ballasting operations began in a pre-arranged manner to keep the bending stresses on the ship within limits and the trim correct, and ensure the maximum draught of the ship was not exceeded. When the ship was fully loaded, no ballast water was normally left on board, so it was important that the cargo was loaded evenly to prevent the ship having a list on departure.

1.6.3 The loadmaster's role was to liaise between the ship and the shore terminal. Requests from the ship regarding the pumping of slurry were made through the loadmaster. At the time of the incident, both the usual loadmaster and a trainee were on board throughout the loading, working a system of 6 hours on and off.

1.6.4 The ship's master had overall responsibility for the ship and hence was ultimately responsible for the loading of it. The first mate was accountable to the master for overseeing cargo loading operations and he co-ordinated the loading, de-canting, de-watering and de-ballasting.

1.6.5 With the exception of the emergency free-water valves and some of the retrofitted free-water valves, the de-canting and de-watering operation could be controlled remotely from the ship's cargo control office located in the accommodation.

1.6.6 De-canting, de-watering and de-ballasting were controlled remotely from the ship's cargo office. The ship's crew were used for taking soundings and operating manual valves in the systems.

1.7 Duct keel electro-hydraulic valve failure and additional pumping measures

1.7.1 The duct keel was a tunnel that extended along the very bottom of the ship's centre line, from the engine room to the forward collision bulkhead. The duct keel contained the pipelines and valves for the de-canting, de-watering, ballast, bilge and fuel systems and the associated control equipment. A service trolley ran on rails down one side to facilitate the movement of personnel and equipment through the space (see Figure 9).

1.7.2 The duct keel sides were formed by the double-bottom tanks, the floor was part of the ship's bottom and the top was part of the inner tank top and the lower stools, where the overflow recesses were located. There were 3 accesses to the duct keel:

- via a watertight manhole in the pump room
- via the weather deck between numbers 5 and 6 holds
- via the weather deck forward of number 1 cargo hold.

1.7.3 A suction pipe in the aft end of the duct keel allowed water to be removed using the bilge system. A bilge alarm was fitted, which activated in the engine control room to alert the duty engineer that water inside had reached a level of about 0.35 m. The volume of the duct keel was about 1850 m^3, not including the common void spaces above.

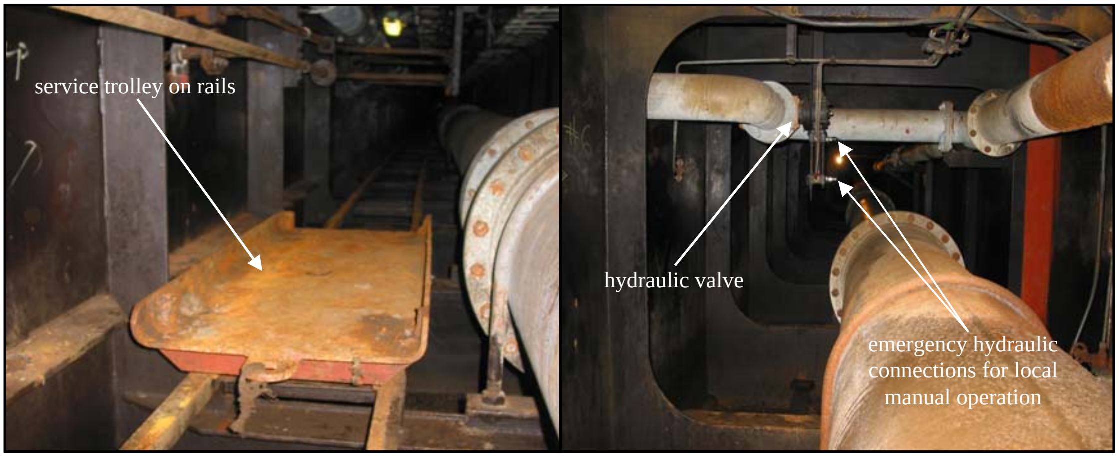


Figure 9
Duct keel

1.7.4 On 18 June 2007, the day the ship arrived in Taharoa, the duct keel sounding was 0.37 m. The duct keel alarm had activated some time earlier that morning and the first mate had been informed. The first mate had other duties when the ship arrived at the port, so he did not start to pump out the duct keel until about 1500, about 2 hours after cargo loading had started. When the first mate stopped the eductor at about 2100, the sounding of the duct keel was about 0.05 m and the bilge alarm had cleared.

1.7.5 On 19 June at about 0500, the duct keel bilge alarm activated in the engine room, but this information was not relayed to the first mate nor did the duty engineer check the duct keel level after accepting the alarm. At about 0800, the 220-volt low-insulation alarm also sounded in the engine control room, indicating a fault in the 220-volt electrical system. It was a lower-priority alarm, so no immediate action was taken to find the fault.

1.7.6 It was not until about 0900 that the chief engineer advised the first mate to obtain a sounding of the duct keel, having investigated the malfunction of number 5 overflow valves and found that 3 electric circuit breakers under the slurry console had tripped. The sounding received at 1000 indicated that the duct keel was flooded.

1.7.7 The tripping of the 3 electric circuit breakers under the console meant that 28 valves in the de-canting and de-watering system were inoperable from the slurry console. The following parts of the ship's systems were affected:

- numbers 5 and 7 holds: unable to remove supernatant water because overflow main suction valves had shut
- numbers 1, 3, 5, 7 and 9 holds: unable to de-hydrate because bilge de-watering valves had shut
- the free-water valves in numbers 5 and 7 holds could only be operated from inside the overflow recess.

1.7.8 By about 1300, ballast operations were suspended because the valves in the ballast system controlled remotely from the slurry console were not functioning. By then the main switchboard circuit breaker in the engine room, which supplied all the breakers under the cargo control console, had tripped.

1.7.9 The cargo control console displayed a mimic diagram of the de-canting, de-watering and ballast systems. Coloured indicator lamps displayed whether the valves of each system were open or closed. The valves for the various systems were operated from the console electro-hydraulically, through solenoids located in the duct keel. There were several different types of valve in use but all operated on the same principle (see Figure 11).

1.7.10 The cargo control console consisted of 2 parts. One part was the ballast, bilge and fuel transfer cargo console from when the ship was built. When the ship was converted, an additional slurry-loading console was added for the de-canting and de-watering systems.

1.7.11 The majority of the valves were located in either the duct keel or the lower stools. The electrical solenoids and wiring that controlled the flow of hydraulic oil to the valve actuators were located in sealed cabinets, also in the duct keel. Hydraulic oil was supplied by pumps located in the engine room.

1.7.12 If there was an electrical or hydraulic failure, valves could be opened or closed locally by attaching a portable hydraulic pump to connections on the valve in the duct keel (highlighted in Figures 9 and 11). If access to the duct keel was not possible, owing to flooding for example, the portable pump could not be used.

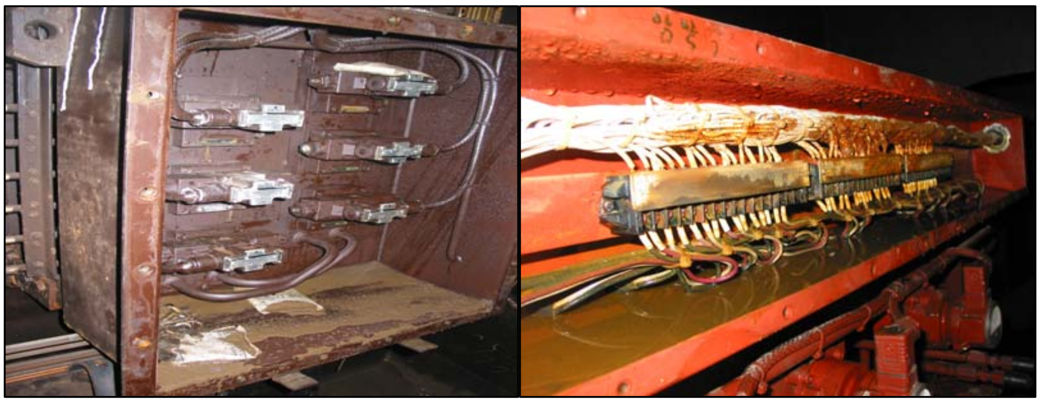


Figure 10
Water ingress to solenoid box (left) and terminal box in duct keel

1.7.13 The solenoid valves and terminal boxes were submerged during the flooding and water got inside, leading to the fault condition that activated the 220-volt earth fault alarm and eventually tripped the circuit breakers owing to excess current (see Figure 10).

1.7.14 Inspection of the valve cabinets showed that most of the seals were in place on the covers of the terminal boxes and cabinets, but the seals had been disturbed in the past for maintenance, as had some of the cable glands. Class NK advised that there were no rules that required the electrical systems from the solenoid valves in the duct keel to be waterproof.

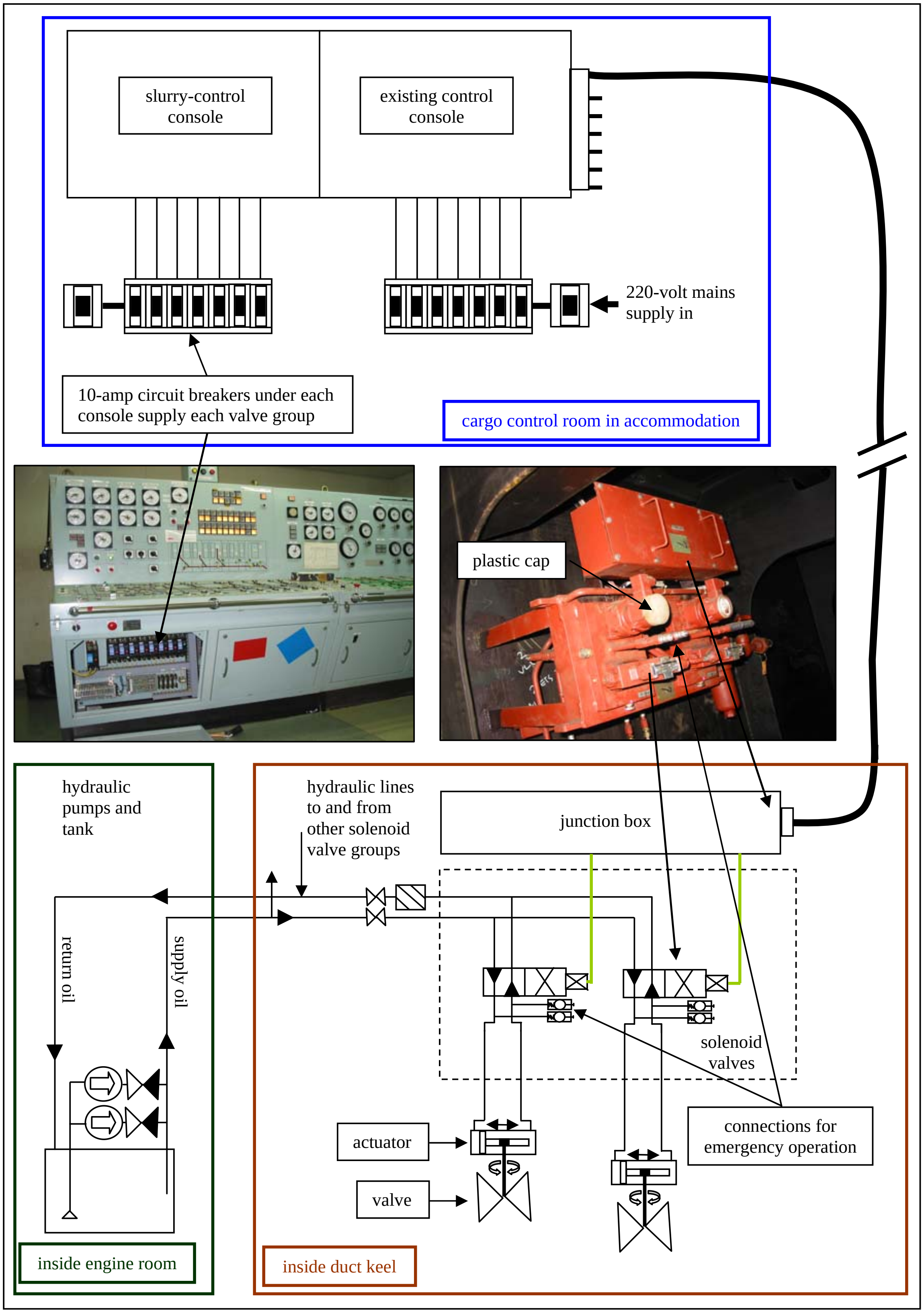


Figure 11
Simplified block diagram of hydraulic valve system components

1.8 Personnel information

1.8.1 The Taharoa *Express* had a crew of 23. These included a Japanese master, chief engineer and first mate; the remainder of the crew were Filipino.

1.8.2 The bridge operated a watch system of 4 hours on and 8 hours off while at sea. At Taharoa the second and third mates worked a 6 hours on and 6 hours off watch system. The first mate supervised the cargo loading in Taharoa and organised his rest periods to suit the loading. The engine room operated the same watch system of 4 hours on and 8 hours off at sea and in port.

1.8.3 The master had sailed in that rank for more than 14 years on tankers and bulk carriers. He had served 3 times as master on the *Taharoa Express*, about 27 months total on board. At the time of the incident he had been on the ship for about 5 months.

1.8.4 The first mate held a master's certificate of competency and it was his second voyage on the Taharoa *Express*. He had spent about 5 months on board in 2006 and had supervised several loadings at Taharoa. He had sailed on a variety of ship types including bulk carriers, oil tankers and container ships. At the time of the incident he was on his first trip since returning to the *Taharoa Express*.

1.8.5 The second mate had held a second deck officer certificate of competency since 1983. He had sailed on a large number of bulk carriers and it was his first trip on the *Taharoa Express*. At the time of the incident he had been on the ship for about 4 months.

1.8.6 The third mate had held a third deck officer certificate of competency since 1999. It was his first voyage on the *Taharoa Express* and second in the rank. Prior to his promotion to third mate he had sailed as an able seaman on predominantly bulk carriers as well as tankers and general cargo ships. At the time of the incident he had been on board for about one month.

1.8.7 The chief engineer was on his first voyage on board the *Taharoa Express* and was about 6 months into his contract at the time of the incident, having joined the ship on 7 January 2007.

1.8.8 The pilot/loadmaster held a New Zealand master's foreign going certificate of competency. He had been at sea his whole career and had more than 40 years' experience as a pilot. Prior to taking up the position at Taharoa he had been an assistant harbourmaster at Nauru for 3 years, followed by 15 years at Christmas Island as harbourmaster and pilot. He had begun work at Taharoa in 1984 and qualified as a pilot for the port in November of that year. In January 1988 he was appointed as deputy harbourmaster for the port, a position he held until January 2007. The pilot/loadmaster operated his own marine consultancy through which he was contracted to NZ Steel Mining to provide the pilot/loadmaster service for Taharoa.

1.8.9 The trainee pilot/loadmaster held a New Zealand master's foreign going certificate of competency. He was under training for his pilot licence at Taharoa and the loading at the time of the incident was his third. He had 12 years' experience as a licensed pilot at Tauranga and was also licensed as a pilot for the port of Gisborne, where he did relief work.

1.9 Repairs in Zhoushan prior to incident

1.9.1 Between 19 April and 2 June 2007, the *Taharoa Express* underwent an intermediate and docking survey including required repairs in Zhoushan, China.

1.9.2 The *Taharoa Express* had a superintendent assigned to it by the ship management company. His role was to provide technical and budgetary support. He was the superintendent most familiar with the ship and had compiled the dry dock and repair specification. However, at the time of the repair period he was already involved in the dry docking of another ship, so could not attend the *Taharoa Express*.

1.9.3 When the *Taharoa Express* arrived in Zhoushan, the ship management company sent the group leader of its ship management division to Zhoushan to arrange the surveys and repairs. On 29 April he was replaced by an assistant superintendent who stayed with the ship until 20 May. On 12 May, an additional assistant superintendent was sent to the ship and remained until its departure. On 28 May the leader of the ship management division returned to the ship to complete final inspections.

1.9.4 The master at the time of the incident was present for the whole repair period. The first mate who had completed the voyage prior to the repair period left the ship on 31 May. On 23 May, the first mate at the time of the incident joined the ship to allow a week's handover from the departing first mate.

1.9.5 The steel replacement in the ship's holds was the largest component of the work to be completed. A total of about 479 tonnes of steel was scheduled for replacement.

1.9.6 The steel-replacement plan was based on thickness measurements. These were taken to determine wastage of steel, and replacement was based on rules and safety standards approved by Class NK under an enhanced survey programme as required under SOLAS Chapter XII.

1.9.7 Relevant to the flooding of the duct keel was the replacement of steel in the tank top, hopper sides and lower stool in the non-cargo-carrying holds numbers 2, 4 and 6.

1.9.8 The lower part of the overflow recess was contained within the centre third of the lower stool space (see Figure 7). Steel replacement of the inner tank top and lower stool in numbers 2, 4 and 6 holds required the removal of steel plate in the overflow recesses of numbers 1, 3 and 5 holds.

1.9.9 Figure 12 is a photograph taken in number 2 hold during the repair period. Highlighted is the steel removed in the inner tank top, lower stool and hopper sides on the port side of the hold. The corrugated bulkhead shown is the forward bulkhead of number 2 hold, which contained number 1 overflow recess. In Figure 13, these areas have been highlighted on a schematic diagram.

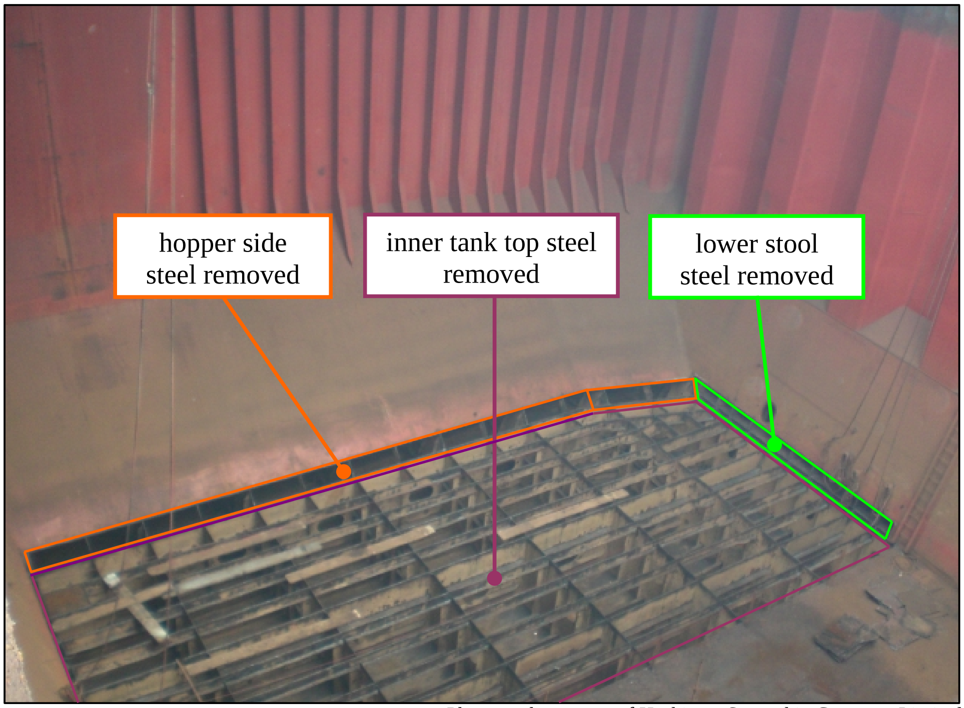
1.9.10 When inserting new steel plate sections into the existing structure, it was necessary, where the joints to be welded dissected existing frames or plates, to cut scallops into the existing plate. These weld access holes were known as "cope holes". The function of the cope holes was to allow the welder access to effect a continuous weld as required by the weld procedure. Once the welding had been completed, the cope holes in the overflow recess side walls should have been sealed (see Figure 14).

1.9.11 After the incident, 3 of these cope holes were found unsealed in the starboard end of number 1 overflow recess and in both ends of number 3 overflow recess. Figure 15 is a photograph taken from inside the lower stool between numbers 3 and 4 holds shortly after investigators boarded the ship. Highlighted are the watertight side bulkhead on the port side of number 3 overflow recess, the seams of the existing and new steel plates and the cope holes.

1.9.12 These unsealed cope holes allowed water overflowing into these overflow recesses to leak into the lower stool and flood the duct keel below while the ship was loading (see Figure 16).

1.9.13 To guarantee the quality of the repairs, they were carried out under the scrutiny of the local Class NK surveyors. The assistant superintendent, who was on board the ship until 20 May, stated that on completion of the repairs in numbers 2, 4 and 6 holds a visual inspection was completed. Only the double-bottom ballast tanks in the area of the repairs were subjected to a pressure test, not the overflow recesses.

1.9.14 The 2 Class NK surveyors who supervised the repairs requiring Class approval had a separate system of approval and reporting to ensure Class rules had been satisfied. In practice this would normally have been done in conjunction with any testing specified by the ship superintendent.



Photograph courtesy of Hachiuma Steamship Company Limited

Figure 12
Steel removed in number 2 hold during repairs in Zhoushan

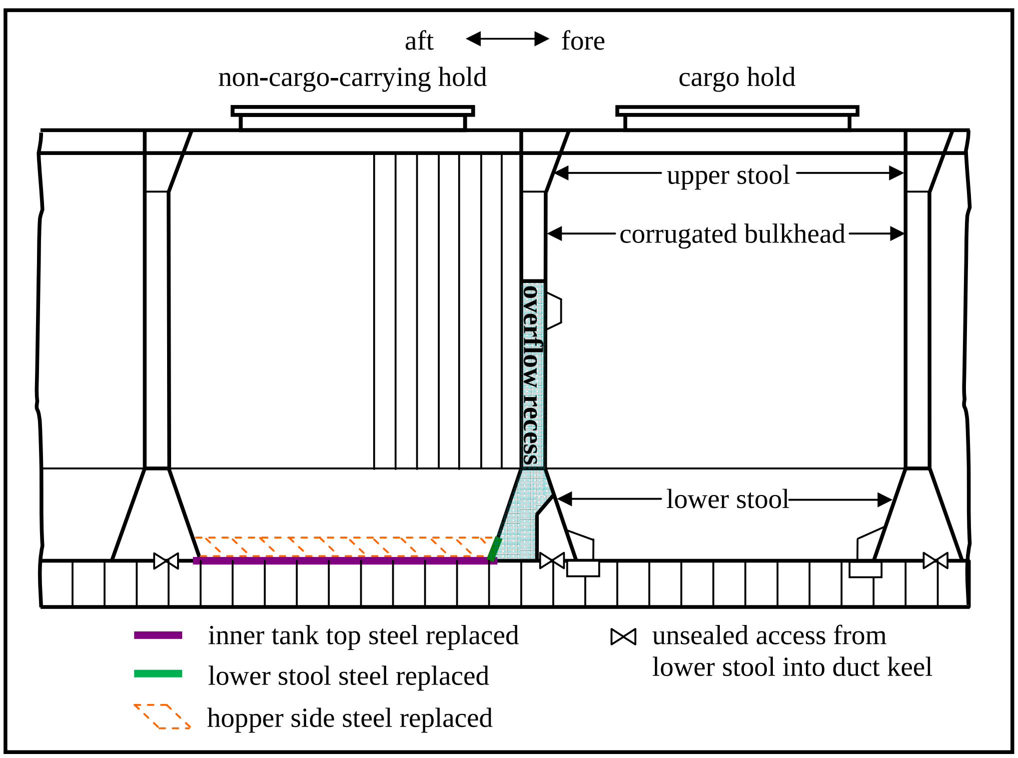


Figure 13
Schematic diagram of steel replaced in non-cargo-carrying hold

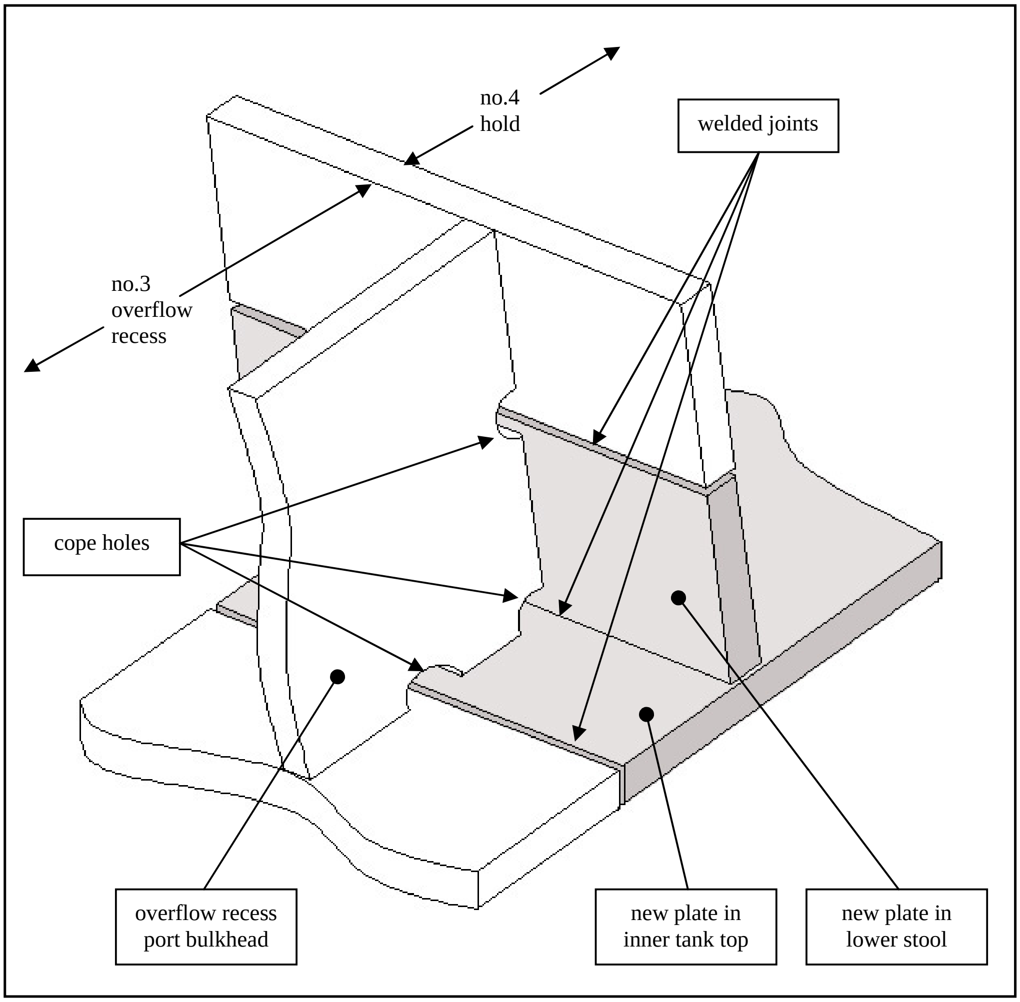


Figure 14
Joint arrangement of new plates and cope holes inside lower stool

1.9.15 An additional inspection of the ship in Zhoushan resulted in other areas of steel being identified for replacement by Class NK. This required the renewal of brackets and stiffeners around several of the hatch lids and coamings on deck, and inside number 5 top-side ballast tank. This put an extra workload on the repair personnel for which no additional time was allocated. The work was completed just before the ship left Zhoushan.

1.9.16 The superintendents interviewed and the ship crews stated that verbal communication between themselves and the dry dock workers was difficult because, in general, the spoken English of the dry dock workers was poor and they did not speak either Japanese or Filipino. English was the working language of the Japanese and Filipino crew on board the Taharoa Express. The language barrier was partly overcome through written communiqués.

1.9.17 Although the dockyard supervisors spoke English, the first mate who joined the ship during the repair period stated that he did not feel that the dry dock workers were supervised sufficiently and often communications to the ship's personnel were erroneous. He said that a number of times, on being told that work had been completed, on checking he found that this was not the case.

1.9.18 The agreed practice between the ship management company and shipyard in confirming that repairs were satisfactorily completed was for both parties to sign off each repair item listed in the repair plan, in line with common practice. The relevant sections of the dry dock specification relating to the steel repairs sighted by the Commission were only signed by either the shipyard representative or the ship owner representative, not both.

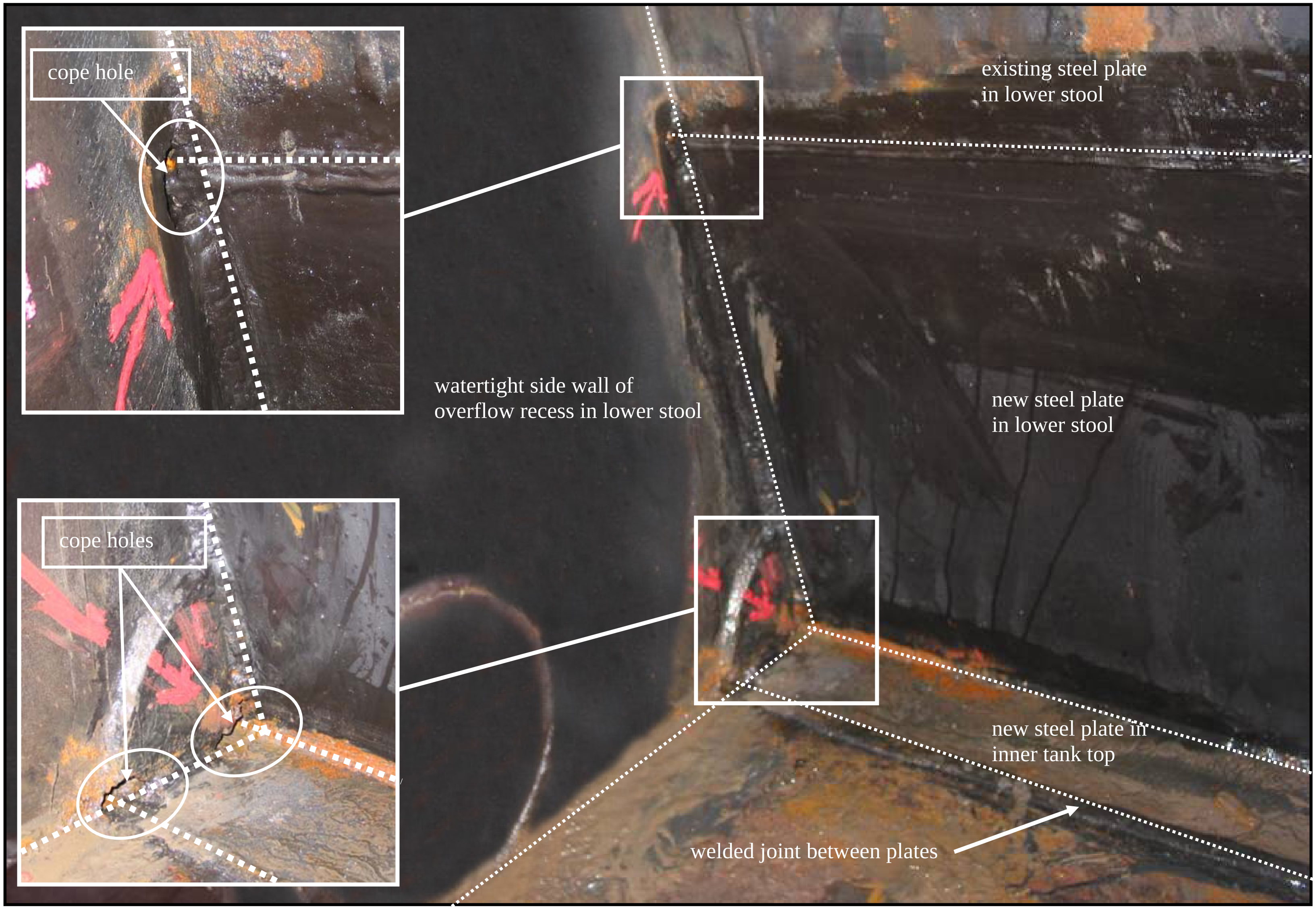


Figure 15
Unsealed cope holes in port side of number 3 overflow recess in lower stool (dotted lines added for emphasis)

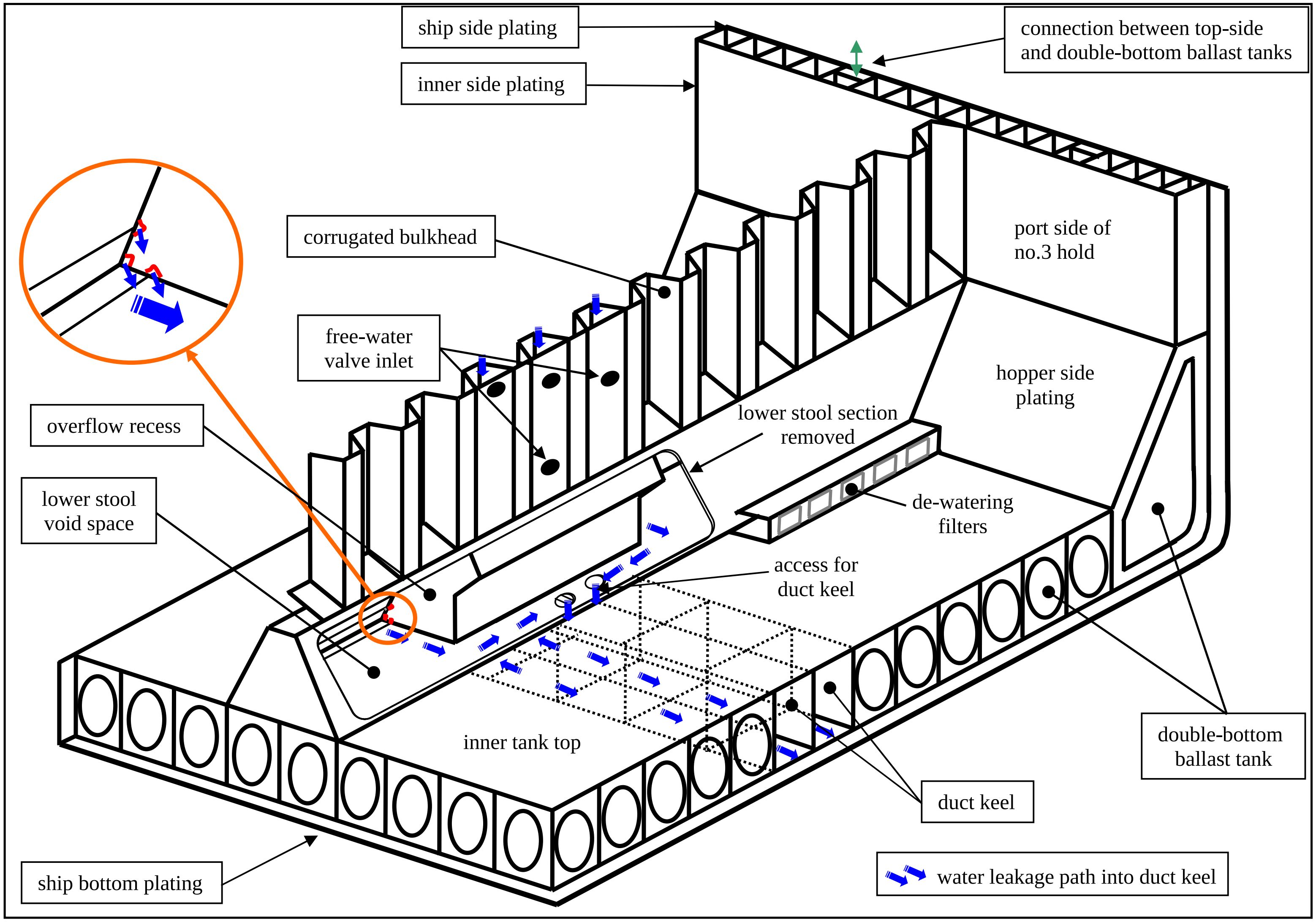


Figure 16
Simplified section of ship showing number 3 overflow recess and leakage path (not to scale)

1.9.19 The ship management company advised the Commission at the time of the incident that it was still awaiting from the shipyard signed copies of documents showing the repairs completed. In the documentation supplied to the Commission by the ship management company, the inner tank top and lower stool steel renewal in numbers 2 and 4 holds was signed off as complete only by the shipyard. This was dated 31 May 2007, 3 days before the ship left the shipyard to resume trading.

1.9.20 On the voyage to Taharoa after the repair period, members of the crew renewed the paint coating in some of the repaired areas of the lower stools, including those containing the unsealed cope holes. However, neither the crew nor officers supervising the work noticed the unsealed cope holes. The overflow system was not tested before the first loading following the repairs.

1.10 Subsequent inspection and damage to ship

Qingdao, 23 September 2007

1.10.1 On 23 September, after the ship had completed another voyage to China following the incident voyage, the ship management company of the *Taharoa Express* requested an occasional survey to be completed by Class NK to approve the fitting of additional free-water valves in the overflow recesses in all the cargo holds. Fitting additional valves was to increase the efficiency of the de-canting process following a review of the incident by the ship management company and NZ Steel Mining. The ship's superintendent attended the ship in Qingdao with a local Class NK surveyor.

1.10.2 The day before the ship was due to leave the anchorage, the master reported to the superintendent that water was flowing overboard from 2 vertical cracks in the shell plating on the starboard side of the ship adjacent to number 1 hold corrugated bulkhead. The cracks were estimated to be about 200 mm and 500 mm long.

1.10.3 Number 1 ballast tank had just been ballasted, so it was assumed that the leak was in the connecting trunk in the double-skin between the number 1 starboard double-bottom and top-side ballast tanks. The ship's side plating formed one of the boundaries of the connecting trunk; Figure 16 shows an identical connecting trunk in number 3 hold.

1.10.4 The ballast tank was emptied and the superintendent entered the tank. He could see no crack in either of the 2 connecting trunks and assumed that the crack was in the double-bottom part of the tank and made no further inspection. The ship's fitter was lowered over the side of the ship to weld over the cracks and fit a doubling plate over them. The tank was then ballasted and no leaks noted from the ship's side.

1.10.5 The superintendent said that after he left the ship at the inner anchorage, he was advised by telephone that a large bulge had been found in the steel plating of the mid access way to the duct keel. Behind the bulged plate was number 6 hold, which was full of ballast water.

1.10.6 The superintendent said that after discussion with his office, the ship was advised to go to the outer anchorage and effect a repair. The superintendent returned home and neither Class NK nor the Port State authorities was advised of the repairs to the ship.

1.10.7 On 25 September the ship was moved to the outer anchorage. At that time the bulge in the access trunk was estimated to be about 10 centimetres. With the approval of the superintendent, the ship's crew welded 2 stiffeners to the bulged plate to add support.

1.10.8 On 26 September, the ship departed for Taharoa, sailing into inclement weather.

1.10.9 On 29 September, the master advised the ship management company that the bulge had increased to about 17 centimetres. A further 2 stiffening brackets were fabricated and welded to the bulged plate to give additional support. To complete the work, the ship altered course to reduce the rolling to assist those making the repairs.

1.10.10 On 1 October another 4 stiffeners were fitted into the space; again the ship had to alter course while the work was carried out. A total of 8 stiffeners had been fitted to the bulged plate.

1.10.11 Approximately 4 days after leaving Qingdao, water was found in the duct keel. The water was ballast from number 6 hold entering through a crack in the aft side of the lower stool between numbers 6 and 7 holds, at the site of a previous repair completed in Zhoushan. The ship's crew stemmed the leak using rubber packing and jacks and advised the ship management company of the situation. Another crack was found in the upper stool between numbers 5 and 6 holds; water from number 6 hold was able to drain into the duct keel via the mid access to the duct keel and lower stool.

Taharoa/Tasman Bay, October 2007

1.10.12 At about 1900 on 12 October 2007, the ship arrived at Taharoa for loading. Shortly after arrival, the condition of the ship was advised to NZ Steel Mining, which raised concerns over the ship's condition with the ship management company. The ship management company then advised Class NK, and requested a surveyor to attend the ship.

1.10.13 At about 0200 on 15 October, the ship departed Taharoa owing to forecast bad weather and sailed to Tasman Bay to seek shelter.

1.10.14 On 17 October, a Class NK surveyor and Maritime NZ maritime safety inspector boarded the ship in Tasman Bay to complete an inspection. An investigator from the Commission also attended.

1.10.15 The Class NK surveyor required a new Class-approved temporary repair to be made to the cracks in the ship's side. This was because in the original repair the crack had not been ground out completely or the ends drilled, and the ship's welder was unqualified. Inspection of the starboard-side double-skin space found it full of water.

1.10.16 Further inspection found that the aft connecting trunk between the number 1 top-side and double-bottom ballast tanks was split on the inboard side. This had allowed the ballast water into the double-skin void space when the ballast tanks were filled. In Qingdao the water then leaked through the ship's hull through cracks in the ship's side.

1.10.17 The side frames 246, 247 and 248 in the starboard side of number 1 hold were cracked. In frames 246 and 247 the cracks had extended into the ship's side plating. There was also a crack in frame 247 on the port side of the ship (see Figure 17).

1.10.18 Figure 18 shows (on the left) the deformation in the bulkhead for emergency fire pump access viewed from number 6 cargo hold after de-ballasting and (on the right) some of the stiffeners fitted by ship's staff inside the access (on the other side of the bulkhead). The Class NK surveyor set out conditions of Class on the ship that permanent repairs were to be made to the bulged plate and lighting in the access trunk when the ship arrived in Qinhuangdao, China. The cargo hold would be empty of ballast water after the ship had loaded in Taharoa.

1.10.19 When inspecting number 1 hold, the Class NK surveyor noticed a previously unrecorded deformation in the corrugated bulkhead and cracks in the ship's side frames adjacent to the corrugated bulkhead, as shown in Figures 17 and 19.

1.10.20 A section of the corrugated bulkhead in number 1 hold had been replaced in Zhoushan in May 2007, because corrosion had reduced the thickness of the steel in this area by more than 25% of the original thickness. The replaced section is shown inside the black dotted area in Figure 19, and the distortion that occurred adjacent to this replaced section is highlighted by a white dotted line.

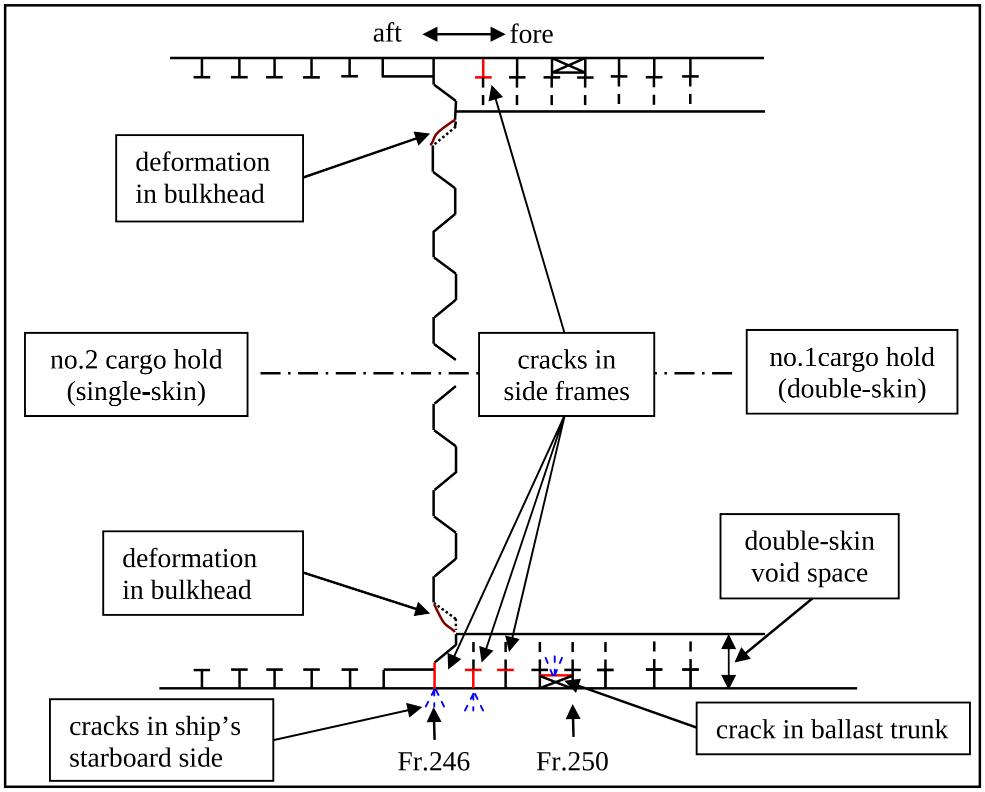
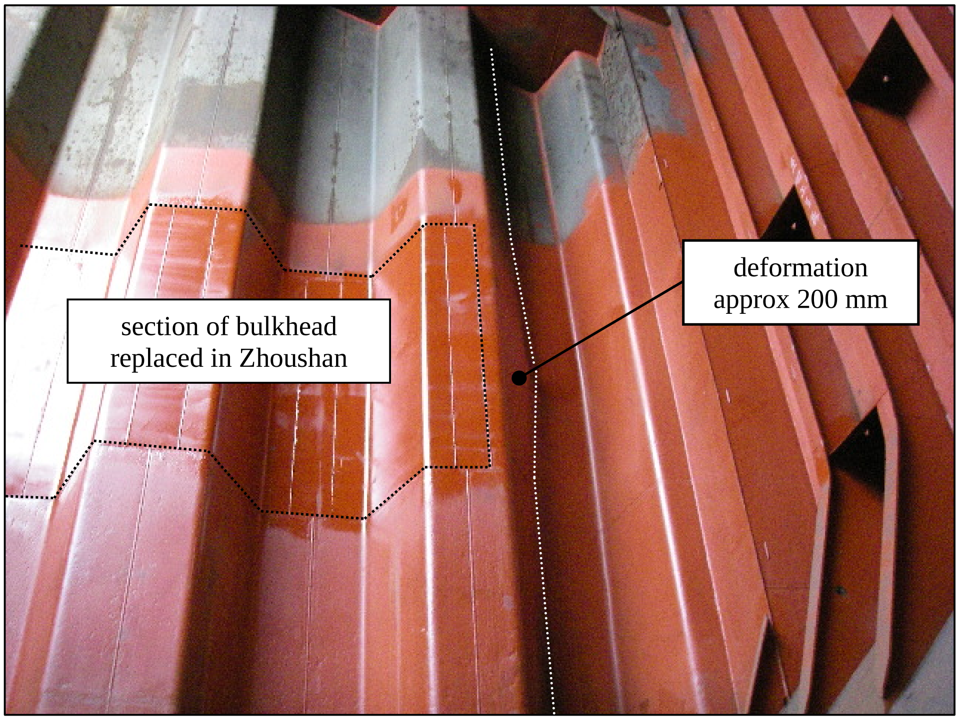


Figure 17
Location of defects in number 1 hold

Left photograph courtesy of Class NK

Figure 18
Bulge and temporary repairs to access trunk wall in number 6 hold

1.10.21 A qualified welder completed temporary repairs to the ship's hull and to the connecting trunk on the starboard side of number 1 cargo hold while the ship was in Tasman Bay. The ship then sailed to Taharoa and commenced loading cargo on 20 October 2007.



Photograph courtesy of Hachiuma Steamship Company Limited

Figure 19
Deformation in starboard side of corrugated bulkhead seen from number 2 hold (dotted lines added for emphasis)

Qinhuangdao, 4 December 2007

1.10.22 At the ship management company's request, Class NK sent a surveyor from its head office in Japan to the ship in Qinhuangdao to report on the condition of the ship's structure and report on whether the recorded structural damage was related to the cargo shift.

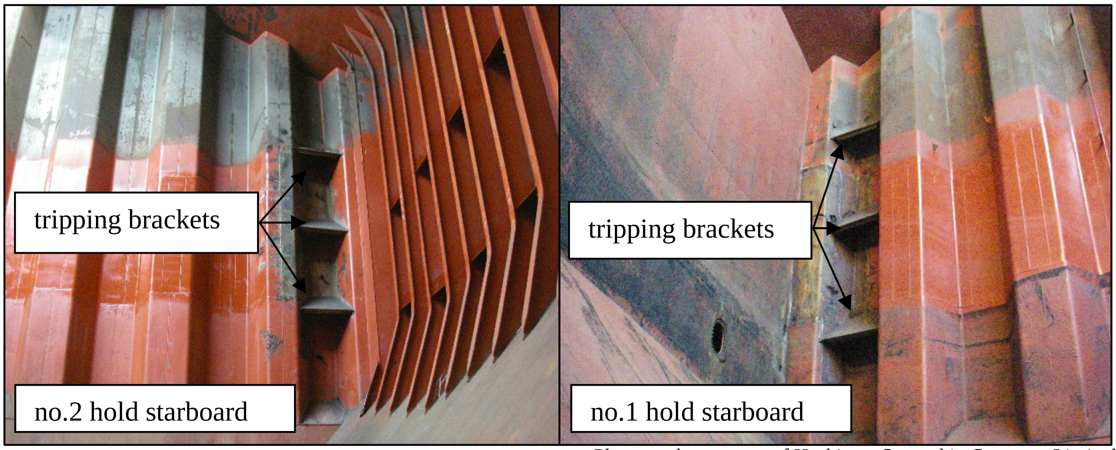
1.10.23 The surveyor completed a close-up inspection and watertight tests of the lower stools and ballast connecting trunks in the cargo-carrying holds and found them to be satisfactory. Observations made by the surveyor contributed to a report produced by Class NK on the listing incident and structural damage to the ship.

1.10.24 On 4 December the permanent repairs to the *Taharoa Express* were completed. The deformed sections in the corrugated bulkhead were replaced with new steel. Although not a requirement of Class NK, extra reinforcement was provided to the bulkhead by fitting tripping brackets at the discretion of the ship owner (see Figure 20). Class NK recorded the wastage of the steel plate removed to be approximately 11%, therefore below the renewal criteria.

1.10.25 The bulged plate in the access trunk in number 6 cargo hold was renewed. Although not a requirement of Class NK, extra reinforcement was provided to the plate by fitting stiffeners at the discretion of the ship owner. No significant wastage was found of the removed bulged plate.

1.10.26 The Class NK report of the incident opined that the bulge in the corrugated bulkhead was a result of the sloshing forces from the free water in the hold on passage from Taharoa to Tasman Bay.

1.10.27 Regarding the cracks in the ship's side, the report opined that they were a result of fatigue owing to the propagation of cracks in the adjacent side frames, also found on the opposite side of the ship. However, there was no clear conclusion that the damage was related to the cargo shift voyage, and that it may have been present before the intermediate survey completed in Zhoushan.



Photographs courtesy of Hachiuma Steamship Company Limited

Figure 20
Repairs to number 1 corrugated bulkhead and tripping brackets

1.10.28 Regarding the bulge in the access trunk wall, the report opined that it was a result of the cargo shift voyage owing to the sloshing forces generated in the part-filled ballast hold exceeding those anticipated in Class rules. The welding of the plate to the corrugated bulkhead was not to the same specification as the corrugated bulkhead; although not considered contributory, the new steel was welded in place using a higher-strength weld procedure.

1.11 SOLAS regulations for loading and unloading bulk carriers

1.11.1 The dangers involved with the carriage of bulk cargoes had been recognised for a considerable time by the bulk shipping industry and the authorities that regulated it. In 1960 it was recommended to IMO that it draw up an international code of practice dealing with the subject. In 1965 the first bulk code was adopted.

1.11.2 The bulk code provided guidance to Administrations, ship owners, shippers and masters on the standards to be applied in the safe stowage and shipment of solid bulk cargoes. The bulk code had been revised several times and was kept under continuous review by the IMO Sub-Committee on Dangerous Goods, Solid Cargoes and Containers. At the time of the incident the bulk code 2004 was in force and it contained practical guidance on the procedures to be taken in the loading, trimming, carriage and discharge of bulk cargoes.

1.11.3 The bulk code 2004 general introduction stated:

1 The primary aim of this Code is to promote the safe stowage and shipment of cargoes by:

.1 highlighting the dangers associated with the shipment of certain types of solid bulk cargoes;

.2 giving guidance on the procedures to be adopted when the shipment of solid bulk cargoes is contemplated;

.3 listing typical cargoes currently shipped in bulk together with advice on their properties, handling and carriage; and

4 describing test procedures to be employed to determine various characteristics of the solid bulk cargoes.

1.11.4 On 27 November 1997, IMO adopted the Code of Practice for the Safe Loading and Unloading of Bulk Carriers (bulk loading code). The bulk loading code was developed to help minimise the losses of bulk carriers and its stated purpose was to assist persons responsible for the loading or unloading of bulk carriers to carry out their functions and promote the safety of bulk carriers.

The code reflected the issues, best practices and legislative requirements of the day. The recommendations were subject to terminal and port requirements and national regulations.[5]

1.11.5 SOLAS 1974 Chapter VI as amended, "the safety of cargoes", outlined the special provisions for the safe carriage of cargoes. The original SOLAS Chapter VI covered only the carriage of grain cargoes; the Chapter was amended to extend its scope to include bulk cargoes other than grain and the revised Chapter entered into force in 1994. Part B of Chapter VI applied to bulk cargoes.

1.11.6 SOLAS Chapter VI specified that both the bulk code and the bulk loading code should be referred to where bulk cargoes were carried.

1.11.7 SOLAS Chapter VI part B, regulation 6.2 stated that:

> concentrates or other cargoes that may liquefy shall only be accepted for loading when the actual moisture content of the cargo is less than its transportable moisture limit (TML). However, such concentrates and other cargoes may be accepted for loading even when their moisture content exceeds the above limit, provided that safety arrangements to the satisfaction of the Administration are made to ensure adequate stability in the case of cargo shifting and further provided the ship has adequate structural integrity.

1.11.8 The requirements of SOLAS 1974 were in New Zealand implemented through Maritime Rules. Maritime Rule, Part 24C Carriage of Cargoes – Specific Cargoes came into force on 1 February 1998 and implemented the specific requirements of SOLAS Chapter VI, part B. This Rule applied to New Zealand-registered ships and foreign ships that undertook either coastal or international voyages after loading bulk cargoes at New Zealand ports; requiring them to load and carry the cargo in accordance with the IMO bulk code.

1.11.9 Maritime Rule 24C advised that the shipper of a solid bulk cargo carried on a ship must provide the ship master or their representative with information that included:

- any relevant special properties of the cargo
- the stowage factor of the cargo
- in the case of a concentrate or other cargo that may liquefy, additional information on the moisture content of the cargo and its TML.[6]

1.11.10 Maritime Rule 24C advised that the owner and master of a ship that carried solid bulk cargo must ensure that cargoes that may liquefy were only accepted for loading when the actual moisture content of the cargo was less than its TML. When the actual moisture content of the cargo exceeded the TML, arrangements to prevent the flow of the cargo were to be implemented to the satisfaction of the Director or the Port State Administration, and the ship had to have sufficient structural integrity for the carriage of solid bulk cargo that may liquefy.[7]

1.11.11 Direct reference to the bulk loading code was not made in Rule 24C. However, reference to the bulk code was made in the Rule and in turn the bulk code made reference to the bulk loading code. This meant that anyone using Rule 24C would be ultimately directed to the bulk loading code as well.

1.11.12 Regulation 4.2.3 of the bulk code, assessment of acceptability of consignments for safe shipment, made references to the bulk loading code. It stated that information provided by the shipper should be accompanied by a declaration. Further information on this cargo declaration was provided in the bulk loading code published by IMO.[8]

[5] Code of Safe Working Practice for the Safe Loading and Unloading of Bulk Carriers, 1997: Introduction (in part).
[6] Maritime Rule Part 24C-24C.3 Cargo Information.
[7] Maritime Rule Part 24C-24C.9 Acceptability for Shipment.
[8] Code of Practice for the Safe Loading and Unloading of Bulk Carriers, Appendix 5.

1.11.13 Section 4 of the bulk code advised that sampling for the TML of solid bulk cargoes that may liquefy should be conducted at regular intervals. Even in the case of materials of consistent composition, the code advised that the test should be completed at least once every 6 months.

1.11.14 In October 2003, shortly before the risk assessment for Port Taharoa was being undertaken, the IMO Sub-Committee on Dangerous Goods, Solid Cargoes and Containers released a circular DSC/Circ.14 to its Member Governments. The circular was in response to a number of incidents where attention had been brought to a lack of adherence to the bulk code. It was intended to be circulated to ship owners, ship operators, companies and charterers involved in the transport of bulk cargoes to bring attention to the provisions of SOLAS Chapter VI and the provisions of the bulk code (see Appendix 4).

1.11.15 IMO has been working to replace the recommendatory bulk code with a new code called the "International Maritime Solid Bulk Cargoes Code" (IMSBC Code) which it intends to make mandatory through amendments to SOLAS Chapter VI by January 2011. IMO states that the aim of the mandatory IMSBC Code is to facilitate the safe stowage and shipment of solid bulk cargoes by providing information on the dangers associated with the shipment of certain types of cargo and instructions on the appropriate procedures to be adopted.

1.12 Cargo shift mechanisms

1.12.1 The bulk code warned about the hazards associated with the shipment of bulk cargoes with respect to structural damage to a ship owing to the improper distribution of cargo and a reduction in stability owing to a shift in cargo. Cargo could shift in heavy weather or because of incorrect loading or because of cargoes liquefying under the stimulus of vibration and a ship's motion in a seaway and sliding in the cargo hold.[9]

1.12.2 Section 7 of the bulk code 2004 brought to the attention of masters and others who had responsibility for the loading and carriage of bulk cargoes, the risks associated with cargo shift and the precautions required to minimise the risk. Cargoes that may liquefy were defined in the bulk code as cargoes that contained at least some fine particles and some moisture, usually water, although they did not need to be visibly wet in appearance. They may liquefy if shipped with moisture contents in excess of their TML. Such cargoes were listed in Group A in Appendix A of the bulk code.

1.12.3 Section 7 also stated that a ship's motion may cause a cargo to shift sufficiently to capsize the vessel. It also stated that cargo shifts could be divided into 2 types, namely sliding failure and liquefaction consequence.[10]

1.12.4 In general the simplest form of sliding was the movement of cargo, when tilted sufficiently for the forces acting on the cargo to cause some of the material to slide down the sides of the cargo. Such sliding could occur in dry cargoes or cargoes containing moisture when a ship rolled, and particularly if the cargo was not level in the hold.

1.12.5 The angle of repose of a cargo was the maximum slope angle that was formed of a non-cohesive, free-flowing granular material poured onto a horizontal surface. It was the angle between a horizontal plane and the cone slope of the material. The angle of repose in a non-cohesive cargo was used to guide the shipper as to the level to which cargo had to be trimmed.

1.12.6 The greater the angle of repose, the more stable the cargo was considered to be. The greater the frictional strength of the cargo, the less likely it was to move. For example, a pile of smooth spheres would collapse to a low slope angle. A cargo of rough and irregular particles would be expected to produce a steeper angle of repose as the particles interlocked. The bulk code explained that all damp cargoes possessed cohesion owing to the presence of moisture.

[9] Code of safe practice for solid bulk cargoes, 2004, general introduction:3.2.2.
[10] Code of Safe Practice for Solid Bulk Cargoes, 2004, Section 7, Cargoes that may liquefy: 7.2.1.

1.12.7 The following description of cohesion has been taken (in part) from a paper by Dr A Kruszewski titled "The shift of bulk cargoes".

> Cohesion can be due to two things:
> (i) True cohesion is due to attraction between fine particles, e.g. flour or clay.
> (ii) In the case of bulk cargoes, the cohesion is more usually due to the presence of moisture. Surface tension causes the moisture to form capillaries which hold the particles together. A child building sandcastles at the beach soon learns that damp sand can be packed into much steeper slopes than dry or wet sand. The same is true of the surfaces of many bulk cargoes. In such materials, the magnitude of the cohesion will vary with moisture content reaching a peak somewhere between dryness and saturation.
> The effect of cohesion also depends on the size of pile of material: the greater the height, the shallower the maximum slope angle we can achieve. For example, with a heap of flour we can cut out a slice an inch or so deep and leave the remainder undisturbed but any more and the remaining sides collapse. Going back to the sandcastles example, we can build walls about a foot high before they start to topple.
> The dependence of cohesion on these two factors: moisture content and height of pile explains why we find such large discrepancies in the tabulated angles of repose for the same material. Thus it is now accepted that, for most cargoes the angle of repose is of dubious value and its use in the code is being phased out.[11]

1.12.8 The bulk code 2004, published after the above paper, stated that the angle of repose was not a reliable indicator of the stability of a cohesive bulk cargo; hence it was not included in the individual entries in the code for cohesive cargoes.[12]

1.12.9 Section 5 of the bulk code explained that trimming a cargo reduced the likelihood of the cargo shifting, and to minimise the risk, cargoes should be trimmed reasonably level.[13] The code advised that to reduce the potential of a shift, cargoes that may liquefy should be trimmed reasonably level on completion of loading irrespective of the stated angle of repose.[14]

1.12.10 The method of loading of the *Taharoa Express* was such that the iron sand slurry entered the hold through a moveable nozzle. The cargo was distributed evenly across the holds to keep the ship upright. It could be considered trimmed reasonably level as recommended in the code.

1.12.11 The bulk code 2004 outlined how a cargo could shift in sections 7.2.5 and 7.2.6, as stated below:

> 7.2.5 A cargo shift caused by liquefaction may occur when the moisture content exceeds the transportable moisture limit. Certain cargoes are susceptible to moisture migration which may develop a dangerous wet base even if the average moisture content is less than the transportable moisture limit.
>
> Although the surface of the cargo may appear dry, undetected liquefaction may take place resulting in shifting of the cargo. It is extremely important to mariners who carry this cargo that they are provided with accurate transportable moisture limit and moisture content values of the cargo. Such cargoes should be trimmed reasonably level and loaded as deeply as practicable. The base of cargoes with a high moisture content are prone to slide particularly when the cargo is shallow and subject to large heel angles.
>
> 7.2.6 In the resulting viscous fluid state, cargo may flow to one side of the ship with a roll one way but not completely return with a roll the other way. Thus, the ship may progressively reach a dangerous angle of heel and capsize quite suddenly.

---

[11] From paper "Shift of bulk cargoes" by Dr A Kruszewski. Marine Environment Group, Warren Spring Laboratory. Also published in Hazardous Cargo Bulletin, April 1989.
[12] Code of Safe Practice for Solid Bulk Cargoes, 2004, Section 5, Trimming procedures: 5.2.3.2.
[13] Code of Safe Practice for Solid Bulk Cargoes, 2004, Section 5, Trimming procedures: 5.1.1.
[14] Code of Safe Practice for Solid Bulk Cargoes, 2004, Section 7, Cargoes that may liquefy: 7.2.7.

1.12.12 Section 7.2.2 stated the liquefaction of Group A cargoes (those which may liquefy) as follows:

> .1 the volume of spaces between the particles reduces as the cargo is compacted due to the ship's motion;
>
> .2 this reduction of the spaces between the particles causes an increase in water pressure;
>
> .3 the increase in the water pressure reduces the friction between particles causing a reduction in the shear strength of the cargo.

1.12.13 The bulk code 2004, section 7.2.3, stated that liquefaction did not occur when one of the following conditions was satisfied:

> .1 when the cargo contains very small particles, the movement of the particles is restricted by cohesion and water pressure does not increase;
>
> .2 when the cargo consists of large particles or lumps, water passes through the spaces between the particles with no increase in water pressure. Cargoes which consist entirely of large particles, will not liquefy;
>
> .3 when a cargo contains a high percentage of air and low moisture content, any increase in water pressure is inhibited. Dry cargoes will not liquefy.

1.12.14 The bulk code 2004, section 7.2.4, stated that cargoes that contained a certain proportion of small particles and a certain amount of moisture may liquefy. Another description giving the mechanism of liquefaction on ships is as follows:

> Cargo liquefaction occurs when a wet cargo is subjected to ship's motion. The water present comes under pressure to drain away in response to the motion by seeping through the pores between solid particles. If the particles are coarse with large pores between them, then the water drains rapidly and the pressure dissipates quickly posing no threat. Similarly, if the cargo is fairly loose and dry, then the water has only a short distance to travel before moving into a void space where the air is squeezed out and the pressure is dissipated. However, if the particles are fine (so the pores between them are small) and the material is wet, then the water takes much longer to escape and it has further to travel before draining away. As a result, the pore water pressure dissipates slowly. If the ship's motion is severe enough, the pore water pressure will build up faster than the rate of decay due to drainage until, eventually, it is equivalent to the weight of the cargo above it. At this point, the cargo or that part of it will liquefy and start to flow.[15]

1.12.15 The loading of cargo as deeply as possible was limited by the ability of the ship's structure not to be overloaded where dense cargoes were shipped. It is one reason why ships were specifically strengthened for alternate loading when loading dense cargoes. Also, the more a cargo hold was filled, the less room the cargo had to shift within it.

1.12.16 The bulk code, section 7.3.3, explained that specially constructed cargo ships that had permanent structural boundaries so arranged to confine any shift of cargo to an acceptable limit could carry cargoes of moisture content in excess of the TMLs. The ships concerned should carry evidence of approval by their Administrations.

1.12.17 There were anecdotal reports that in the past the *Taharoa Express* had sailed from Taharoa at short notice owing to deteriorating weather at various states of loading, often with free water remaining on top of the cargo. A cargo shift had not been reported on any of these occasions.

1.13 Post-incident analysis of cargo shift

1.13.1 After the incident NZ Steel Mining commissioned an independent company to conduct a study into the behaviour of the iron sand on the incident voyage. The Commission invited comment on the study findings from an independent expert in the field of bulk cargoes.

[15] Extract from paper "Liquefaction of solid bulk cargoes" by Dr A Kruszewski.

1.13.2 The NZ Steel Mining study tested a number of potential causes that may have singly or in combination induced the recorded ship list incident:

1. Wind
2. Initial ship list
3. Water depth over the sand
4. Liquefaction of the sand.

1.13.3 Part of the study involved model testing using a 1:33 scale model of the ship's hold made of Perspex; it did not replicate the sloping sides of the hold. Different levels of sand and water were used to reflect the actual conditions in the various holds. The interaction of the free water and iron sand was observed as the tank was rocked back and forth over varying time periods.

1.13.4 One set of tests was conducted with the tank being tilted evenly about its centre to simulate a ship rolling on an upright axis (without a list). Other tests were conducted tilting the tank unevenly about an axis, simulating a ship with a permanent list (see Figure 21).

1.13.5 In brief summation, the results showed that for a ship rolling about an upright axis (no list) there was no resultant transverse shift of sand. There was some local redistribution of the sand noted at the extremities of the tank.

1.13.6 When a permanent list was simulated, the iron sand would move across from the high to the low side. The mechanism for the shift of the sand was by erosion on the high side where the sand was exposed, then entrainment and gravitation to the low side. In simple terms, the wave action on the exposed beach on the high side entrained some sand and carried it back with each wave as it receded to the low side.

1.13.7 The report stated that the water depth over the cargo was considered a key factor in the mechanism that caused the cargo to shift, in particular in combination with an initial list and the violent rolling by the sinusoidal 4.5 m up to 8 m swell.

1.13.8 The report also stated that:

> … the sand erosion mechanism is exacerbated where the sand in the holds is covered and uncovered and then exposed on the higher side to wave action, when induced a cumulative transverse movement of the sand to the lower side. Given the varying depths of free water in the five cargo holds, the exposure of the sand to wave erosion could occur at different times depending on the angle of the ship's list. For example #1 hold would have sand exposed at about 6º list, Holds #3, 7 and 9 at about 12º and Hold #5 at about 20º. It would be likely that the sand in Hold #1 would be shifted first at the highest rate and as the ship list angle increased the sand in Holds #3, 5 and 7 would have increased rapidly. Sand movement in Hold #5 would have likely occurred in the later stage of the incident.

1.13.9 To analyse the possibility of liquefaction being a factor, a model test was carried out using a Perspex tank containing saturated iron sand on a gradient across the width of the tank. To simulate the shudder/crash effects owing to free water hitting the hatch sides, the side of the tank against which the iron sand rested was hit with a mallet every 10 seconds. The tank was tilted to various angles and iron sand could not be induced to flow; the sand was observed to exhibit a wet sheen on its surface at the time of impact from the mallet then immediately dry out. The report stated that the test showed that even under extreme conditions, a saturated sand cargo could not be induced to flow or move to any significant degree.

1.13.10 The report stated the following regarding the cargo behaviour:

> The reported "shudder/crash" would have been caused by the waves crashing at the ends of the holds due to the violent rolling action induced by the swells. It is not known if such shock caused liquefaction in the holds.
>
> Assuming that sand liquefaction did occur temporarily due to the waves crashing against the end walls, this would have been short lived, followed in the subsequent 10 seconds of waves rushing to the other side of the hold.
>
> The sand would likely compact down as a result of the shock, and some very minor settlement or very small movement may result. The pore pressure increase created by the shock would dissipate rapidly releasing some water and the slight movement of the sand would turn the positive pore pressure to negative pore pressure, "locking" or stabilising the sand mass, holding it against further movement.
>
> It is also noted that once the sand had been compacted, further shocks would unlikely cause much further movement, unless the shocks were more violent or of much longer duration.
>
> It is therefore not expected that liquefaction to have been a mechanism that would be a significant cause of mass cargo shift as reported in this incident.

The report conclusion regarding liquefaction stated:

> We consider that temporary liquefaction may occur if the holds were violently shaken, however we do not believe that sand liquefaction was a mechanism that would be a significant cause of the mass cargo shift reported in the incident.

1.13.11 The NZ Steel Mining-commissioned report recommended that the operators of the Taharoa Express consider:

1. Minimising the number of holds with free water above the cargo
2. Removing free water as soon as possible, before critical weather conditions are in force
3. Correcting any residual list (as practicable) if any free water remains in the hold(s) before departing.

1.13.12 The Commission took advice from an independent bulk cargo expert.16 He was asked to comment on the NZ Steel Mining report and he advised that while he felt that water washing at the surface of the sand was the most likely cause in this particular case, to the possible list of causes should have been added a slippage of cargo "en masse" across the base of the hold. The reason was that the holds contained considerably less cargo than would normally be expected and the cargo was saturated. Slippage would depend upon factors such as the friction between the iron sand and the hold base, the shape of the base and the depth of the cargo and the support that the cargo received from the sides of the hold.

1.13.13 The independent expert expressed the opinion that comments in the NZ Steel Mining report regarding liquefaction not being a factor in this incident were probably true, although a larger-scale test would help to confirm them, and it would be useful to know the effects of the ship's motion and vibration from the engine, as well as slamming.

1.13.14 The same expert was of the opinion that the iron sand from Taharoa may have been comparatively safe from liquefaction because it drained so readily that the pore pressure never (or exceptionally) built up to levels that caused liquefaction.

1.13.15 Following the incident, NZ Steel Mining also sent a sample of iron sand from Taharoa for testing. The results of the test were that the iron sand sample provided had a TML of 9.27% and an angle of repose of 50°. NZ Steel Mining advised the Commission that the most recent test

[16] A scientist with more than 10 years' experience in the field of bulk cargo behaviour who was part of a group that undertook research in the area of solid bulk cargo stability for the Department of Transport (UK). Some of this work was submitted to the IMO sub-committee responsible for legislation regarding the safe carriage of bulk cargoes. He was also a consultant to both the UK government and the shipping industry.

had been carried out on the iron sand in September 2006 while conducting experimental trials on iron sands. The result of the test on the existing iron sand product was a TML of 8.26%.

1.13.16 NZ Steel Mining commissioned a firm with geothermal engineering expertise in June 2008 to comment on the findings of its own report, and to assess whether the Taharoa iron sand would be capable of liquefaction and specifically whether it would be possible for it to liquefy and move during the normal loading and de-watering process, and on the carriage voyage. The findings largely echoed the findings of the NZ Steel Mining report, but the report did comment that with free water above the cargo, the surface of the cargo possibly would liquefy when subjected to cyclic energy (vibration and wave action). The report was not specific as to the depth at which it would liquefy, but commented that this would be dependent on the water pressure on the cargo surface (proportional to the water depth above it).

1.13.17 The report also suggested that resistance to liquefaction of the iron sand in the cargo holds increased with cargo depth owing to a decreasing pore water pressure and increasing bulk density of the cargo; the increasing bulk density owing to compaction of the cargo, and the decreasing pore water pressure because the water was being filtrated out from the bottom of the hold through the de-watering process.

1.14 Post-incident investigation into ship stability and sloshing forces

1.14.1 Calculations done by the first mate using the ship's stability program for the departure condition showed that the GM of the ship was 7.27 m, indicating a large reserve of stability with a consequential short rolling period. The stability program could not calculate the effect of the free water in the holds on the GM of the ship and no other calculations were carried out to estimate the actual GM of the ship owing to these effects.

1.14.2 The stability program was used to calculate the static shear forces and bending moments at the bulkheads of each of the ship's holds based on the contents of the ship's tanks and ballast holds and the combined weight of iron sand and water in the cargo holds. The maximum shear force and bending moments calculated by the ship's computer were within the limits allowable set by the stability program for the ship in the ocean/or sea-going mode.

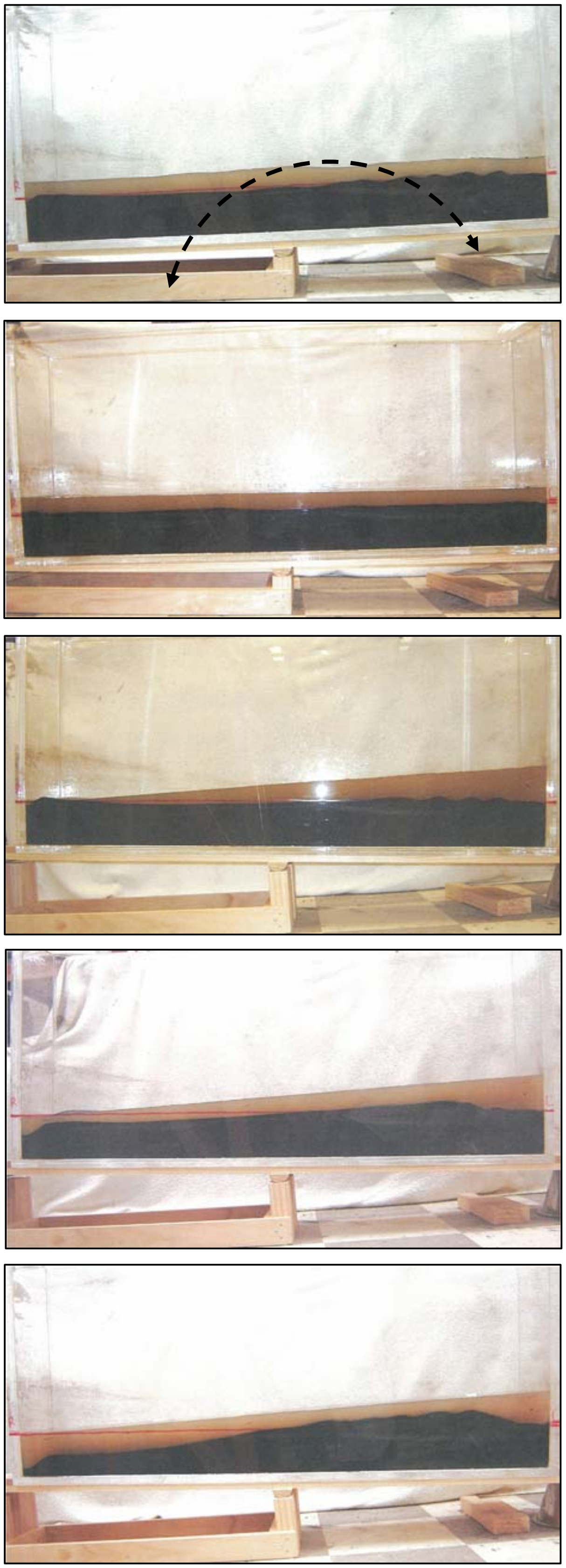
1.14.3 The highest shear force was calculated to occur around number 4 hold. The maximum allowable shear stress was not uniform over the ship's hull; the largest shear stress expressed as a percentage of the maximum allowable at any one point was at the aft bulkhead in number 1 hold, calculated at 80%.

1.14.4 The highest bending moment was calculated to occur around number 4 hold. The maximum allowable bending moment was not uniform over the ship's hold and the largest bending moment expressed as a percentage of the maximum allowable at any one point was at the aft bulkhead in number 1 hold, calculated at 81%.

1.14.5 The Commission for the purpose of the investigation engaged an independent marine consultant in the UK to evaluate the sloshing loads in the ship's holds owing to the free water on board on the incident voyage to see if the design criteria of the ship's structure had been exceeded.

1.14.6 The same consultant was used to provide an assessment of the ship's stability on the incident voyage, taking into account the effects of free surface water in the holds and the shift in the cargo.

1.14.7 The results of both these assessments are appended to this report and the results are discussed in the analysis.



Elapsed time: 0 mins
List of 4º
+/- 5º roll applied.

Elapsed time: 20 mins

Elapsed time: 40 mins
20 mins 4º list and
20 mins 8º list.

Elapsed time: 60 mins
20 mins 4º list and
40 mins 8º list.

Elapsed time: 80 mins
20 mins 4º list and
60 mins 8º list.

Figure 21
NZ Steel Mining study of cargo shift mechanism

1.15 IMO and its conventions

1.15.1 IMO was the agency of the United Nations with the objective of providing for the safety and security of ships at sea and the prevention of marine pollution from ships. IMO facilitated this through a number of international conventions to maintain a regulatory framework for shipping worldwide.

1.15.2 The implementation and enforcement of the conventions adopted by IMO were the responsibility of the individual member countries of IMO, known as "Flag States". When a member government accepted an IMO convention, it agreed to make it a part of its own national law and enforce it (see Figure 22).

1.15.3 The 1914 SOLAS convention was adopted by a diplomatic conference in response to the sinking of the *Titanic* in 1912. Since its inception, SOLAS has been amended several times and at the time of the incident SOLAS 1974 as amended was in force through IMO.

1.15.4 The main objective of SOLAS was to specify minimum safety standards for the construction, equipment maintenance and operation of ships. IMO required the Flag States that had ratified the Convention to ensure the ships under their flags complied. Control provisions also allowed Contracting Governments to exercise Port State control by inspecting ships flying the flags of other Contracting States when there were clear grounds for believing that a ship or its equipment did not comply with the requirements of the Convention.

1.15.5 SOLAS 1974 Chapter VI dealt with the safety of cargoes and part B of the Chapter outlined the requirements for bulk carriers and is discussed in more detail in section 1.11 of this report.

1.15.6 SOLAS 1974 Chapter XII dealt with bulk carriers and outlined specific requirements for the structural and survivability requirements of bulk carriers. Chapter XII had been adopted in response to the high number of casualties involving bulk carriers during the 1980s and 1990s.

1.15.7 SOLAS Chapter XII came into force on 1 July 1999. A further review of bulk carrier safety, using a formal safety assessment, was completed to assess what further improvements could be made through regulations. Chapter XII had been amended several times to reflect the recommendations from the formal safety assessment and other studies on bulk carriers completed by subcommittees within IMO and external organisations such as the International Association of Classification Societies (IACS, see 1.17).

1.15.8 Chapter XII set out requirements not only for new bulk carriers but also for existing bulk carriers. IMO had identified that the majority of bulk carrier losses involved older tonnage. Existing bulk carriers already in service that did not comply with the new regulations were required to either undergo structural changes or limit the type of cargo they carried or loading pattern by certain dates, such as in regulation 14 mentioned earlier.

1.16 Ship classification

1.16.1 A classification society was a non-governmental organisation that contributed to the development and implementation of technical standards for the protection of life, ships and the environment. A classification society established rules to apply the technical requirements for the design, construction and surveys of ships. The periodic surveys of ships within a classification society's register by one of its surveyors ensured its rules were maintained.

1.16.2 A classification society was not a guarantor of the safety or seaworthiness of a ship, because it had no control over the operation of the ship or how it was maintained between the periodic surveys it conducted.

1.16.3 It was the duty of the owner or its representative to inform the classification society for the ship of any events or circumstances that affected the Class of the ship. If a ship was not maintained within the criteria laid down by the classification society, its Class could be suspended or eventually withdrawn.

1.16.4 SOLAS Chapter II-I, regulation 3-1 stated that, in addition to the requirements of the other (SOLAS) regulations, ships should be designed, constructed and maintained in compliance with the structural, mechanical and electrical requirements of a classification society that was recognised by the Administration in accordance with the provisions of regulation XI/I or with applicable national standards of the Administration, which was to provide an equivalent level of safety. It was not a requirement therefore for a ship to be in "Class", however the majority of ships were in Class as it provided a number of advantages with respect to providing documentary evidence that the ships had been built and maintained to correct specifications.

1.16.5 SOLAS and other international conventions permitted the Flag State Administration to delegate the inspection and survey of ships to a Recognised Organisation. IMO Resolution A.739(18) laid down the minimum standards for Recognised Organisations acting on behalf of an Administration. IMO Resolution A.789(19) laid down the minimum specifications for Recognised Organisations performing statutory functions on behalf of Flag State Administrations in terms of certification and survey.

1.16.6 Class NK met the criteria of IMO Resolutions A.739(18) and A.789(19). Panama was the Flag State of the Taharoa Express. The survey of the ship to prove compliance with SOLAS and other IMO conventions for safety and pollution was delegated by Panama to Class NK.

1.16.7 On the Taharoa Express Class NK was responsible for the inspection of the ship to ensure compliance with the following conventions and issue of certificates:

- Cargo Ship Safety Construction Certificate (SOLAS 1974, as amended)
- Cargo Ship Safety Equipment Certificate (SOLAS 1974, as amended)
- Cargo Ship Safety Radio Certificate (SOLAS 1974, as amended)
- Safety Management Certificate (ISM Code [see 1.18])
- International Load Line Certificate (International Convention on Load Lines 1966)
- Pollution Prevention Certificate (International Convention of Pollution from Ships 1973).

1.17 The International Association of Classification Societies

1.17.1 IACS was an organisation that consisted of a number of classification societies that between them had in Class 92% to 95% of the world's cargo fleet by gross tonnage.

1.17.2 The stated main purpose of the organisation was:

> To work towards the improvement of standards of safety at sea and the prevention of pollution of the marine environment, to provide for communications and co-operation with relevant international and national marine organisations and to co-operate closely with marine industries of the world. Each Member Society is to promote the aims which the Association holds in common. Activities by Member Societies which are not associated with this purpose shall not fall in the jurisdiction of this charter.[18]

1.17.3 IACS made its own resolutions on technical and procedural matters and had unified certain rules regarding the classification of ships and compliance with the standards laid down by IMO.

1.17.4 In March 2002, IACS published a set of retroactive guidelines for existing bulk carrier ships designed to enhance the future safe operation of those ships still in use. Class NK as a member of IACS adopted the recommendations and in July 2003 published its own set of the guidelines for use by its surveyors when surveying existing bulk carriers. These were updated on several occasions and the last publication of these guidelines, "bulk carrier safety retroactive requirements for existing bulk carriers", was updated in February 2007.

[18] IACS Charter as amended and agreed by the council, January 2005.

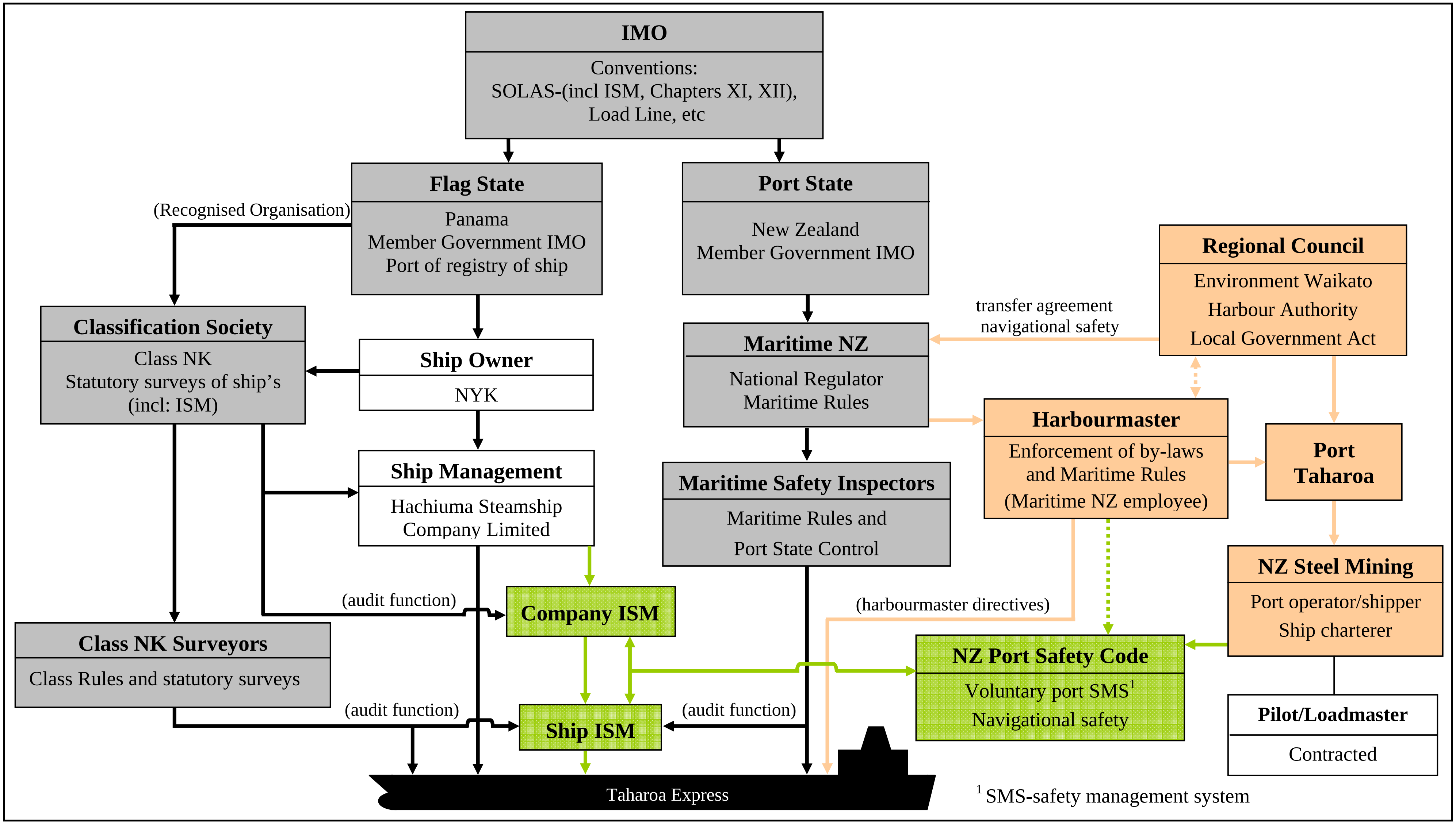


Figure 22
Maritime regulatory structure

1.18 International Safety Management Code

1.18.1 In 1993 IMO adopted the International Safety Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code).

1.18.2 The regulatory requirements of IMO Member States under the ISM Code were set out in SOLAS Chapter IX, ISM. The ISM Code became mandatory in 1998. At the time of the incident, the ISM Code 2002 provided standards to be followed by Flag State Administrations and by ship owners and ship managers responsible for the operations of ships.

1.18.3 The stated objectives of the ISM Code 2002 were:

> 1.2.1 The objective of the ISM Code was to ensure safety, to prevent the injury or loss of life, and to avoid damage to the environment, in particular marine environment, and to property.
>
> 1.2.1 Safety management objectives of the company should, inter alia:
>
> .1 provide for safe practices in ship operation and a safe working environment;
>
> .2 establish safeguards against all identified risks; and
>
> .3 continuously improve safety management skills of personnel ashore and on board ships, including preparing for emergencies related both to safety and environmental protection.

1.18.4 Section 1.2.3 of the ISM Code stated that the safety management system should ensure:

> .1 compliance with mandatory rules and regulations; and
>
> .2 that applicable codes, guidelines and standards recommended by the Organisation, Administrations, Classification Societies and marine industry organisations are taken into account.

1.18.5 It was a requirement of SOLAS Chapter IX that each ship be operated by a company that had a safety management system in place and a current Document of Compliance, and that each ship operated by that company have a safety management system and a current Safety Management Certificate.

1.18.6 The company Document of Compliance was valid for 5 years subject to annual verification, and the ship's Safety Management Certificate, which was also valid for 5 years, was subject to verification once every 2 to 3 years. Verification was by audits conducted by the Flag State Administration or an organisation recognised by the Administration. On the *Taharoa Express*, Class NK as the Recognised Organisation of Panama conducted ISM verification.

1.18.7 On 7 September 2002, the ship had been issued with an initial Safety Management Certificate. On 22 October 2002, a new Safety Management Certificate had been issued that was valid until 22 February 2011.

1.18.8 Following 2 incidents involving the *Taharoa Express* at Port Taharoa: the breaking of a single buoy mooring rope in September 2003 and an engine failure in February 2004, the ship management company had prepared a set of shipboard contingency plans for the *Taharoa Express* for use at the port. These were designed to complement the existing generic contingency plans held on board the ship under ISM and were contained in a separate operational procedures manual for Port Taharoa.

1.18.9 In April 2004 the first set of contingency plans was issued. The plans were reviewed several times during 2004 and 2005 and at the time of the incident the sixth and latest version of the operational procedures manual for Taharoa was in use. Copies of issues 5 and 6 were in the ship's cargo office when investigators boarded the ship in Tasman Bay.

1.18.10 A separate loading instruction manual was held on board that supplemented the NKK loading instruction manual provided to the ship following its conversion to a slurry carrier. Issue 4, dated 14 July 2006, was in use at the time of the incident. Several sections were written predominantly in Japanese with incomplete translation into English, the working language of the ship.

1.18.11 On 13 December 2004, following formal safety assessment studies of bulk carriers, IMO issued a Maritime Safety Committee (MSC) circular (MSC/Circ.1143) called "Guidelines on the early assessment of hull damage and possible need for abandonment of bulk carriers". Member Governments were invited to urge companies that operated bulk carriers flying their flags that in particular may not withstand flooding of any one cargo hold to issue ship-specific guidance to the masters of such bulk carriers.

1.18.12 The guidelines highlighted a number of causes of damage and failure, which included sloshing forces in partially filled ballast holds leading to structural damage, and external forces that could dislodge hatch covers. Records of bulk carrier losses indicated that in a large proportion of cases studied, ships' masters appeared unaware of the imminent danger they were in. Many had lost their lives as did other seafarers on board as a consequence. The guidelines advised that an early assessment of the situation was therefore imperative, combined with alerting a marine rescue co-ordination centre, alerting all personnel on board and making preparations for evacuation.

1.18.13 The ship carried on board the MSC circular 1143; however, it was not integrated or referenced into the ISM system contingency plans, which also did not contain the specific guidance given in the circular.

1.19 Port State control inspection

1.19.1 Ship owners or their designated management companies, and ships' masters, were responsible for ensuring compliance with Flag State regulations. Compliance was enforced by the Flag States where ships were registered through statutory surveys.

1.19.2 IMO also made provision for Member States to inspect ships of other Member States that visited their ports, known as Port State control inspections. A Flag State inspection was the inspection of a ship by the Flag State authority inspectors where the ship was registered.

1.19.3 Port and Flag State control in New Zealand was exercised by Maritime NZ; these inspections of both New Zealand- and foreign-registered ships were conducted by maritime safety inspectors. If any serious deficiencies were found, a ship could be detained, or in the case of a less serious deficiency, a timeframe given in which it was to be rectified.

1.19.4 Port State control was regarded as complementary to Flag State controls and was believed to be more effective when organised on a regional basis. New Zealand was a member of the Tokyo Memorandum of Understanding (MOU). The Tokyo MOU of Port State control in the Asia Pacific region was agreed in December 1993. The MOU was drawn up between 18 member countries and was one of a number established in different areas of the world.

1.19.5 The Tokyo MOU provided for a harmonised system of Port State inspection designed to target substandard ships. This was achieved by maintaining a database of inspections of, and the deficiencies found on, each ship. A numerical system was operated whereby the higher the number of points awarded, the greater the risk of non-compliance a ship was perceived to have, and the more inspections it required. More points were awarded for older ships with recurring deficiencies. Other factors such as the time since last inspection and the Flag State's overall inspection history were also taken into account.

1.19.6 Under the Tokyo MOU the Taharoa Express had had a total of 25 Port State inspections between 16 October 2000 and 26 April 2006. Twenty of these had been conducted at Taharoa by Maritime NZ and one in Qinhuangdao, China in 2005. The ship had had 3 Port State control inspections in Australia and one in Japan between 2001 and 2003.

1.19.7 From these inspections a total of 61 deficiencies had been recorded. Generally these had been rectified in the agreed timeframes. None of the deficiencies had been serious enough to warrant detention of the ship.

1.19.8 The inspection rate was similar to those of other bulk carriers of a similar age under the Tokyo MOU and on average the ship was inspected every 3 months.

1.19.9 In 2004, the chartering arrangement for the Taharoa Express changed owing to commercial reasons. NZ Steel Mining recognised that as the exporter it had an obligation to vet the condition of the ship. These inspections were completed every 18 months by an independent surveyor.

1.20 The New Zealand Port and Harbour Marine Safety Code

1.20.1 Between February 2002 and July 2003 a total of 4 ships grounded in New Zealand harbours. They were:

- the log carrier *Jody F Millennium*, February 2002 in Gisborne Harbour
- the bulk carrier *Tai Ping*, October 2002 in Bluff Harbour
- the oil tanker *Capella Voyager*, April 2003 in Whangarei Harbour
- the oil tanker *Eastern Honor*, July 2003 in Whangarei Harbour.

1.20.2 These groundings caused concern over the safety management in New Zealand ports and harbours. Maritime NZ in its report on the grounding of the *Jody F Millennium* recommended that:

> the Director of Maritime Safety and the Ministry of Transport give consideration to the introduction of a port marine safety code and/or appropriate Maritime Rules establishing a standard marine safety code for the operation of New Zealand commercial ports, similar in nature to the United Kingdom Port Marine Safety Code (and accompanying Guidelines) published by the UK Department of Environment and the Regions (DETR) in March 2002.

1.20.3 In August 2004, the New Zealand Port and Harbour Marine Safety Code (port safety code) was approved. The port safety code was modelled on the UK Port Marine Safety Code and was developed by Maritime NZ with representatives of local government and the port and marine industries.

1.20.4 The port safety code was a framework for the preparation of safety management systems, based upon formal risk assessments.

1.20.5 The objectives of the port safety code were to provide for the safe management of vessels in New Zealand's ports and harbours, including the prevention of human injury or loss of life, and the avoidance of damage to the environment, in particular to the marine environment and to property.

1.20.6 The stated safety management objectives of the port safety code were to:

(a) provide for safe practices in port operation and a safe operating environment in the harbour;

(b) identify all risks and establish safeguards to ensure that all identified risks are kept as low as reasonably practicable; and

(c) continuously improve safety management skills of all personnel, including preparation for emergencies related to both safety and environmental protection.

1.20.7 The port safety code stated that the safety management system was to ensure:

(a) Compliance with mandatory rules and regulations; and

(b) That applicable codes, guidelines and standards recommended by the Maritime Safety Authority [Maritime NZ] are taken into account.

1.20.8 The port safety code 2004 was supported by 6 sets of guidelines:

- Port and Harbour Risk Assessment and Safety Management Systems in New Zealand
- Guidelines of Good Practice for Hydrographic Surveys in New Zealand Ports and Harbours
- Guidelines for Providing Aids to Navigation in New Zealand
- Environmental factors affecting safe access and operations within New Zealand Ports and Harbours
- Guidelines for Aquaculture Management Areas and Marine Farms
- Safety Management of Power Line Waterway Crossings.

1.20.9 Section 3 of the Risk Assessment guidelines detailed the recommended 5 stages of a risk assessment:

- Stage 1 Data Gathering and System Assessment
- Stage 2 Hazard Identification (HAZID Meeting)
- Stage 3 Risk Analysis
- Stage 4 Assessment of existing management strategies, development of new measures; Assessment of Control Adequacy rating
- Stage 5 Managing and Treating the Risk via the Port and Harbour Safety Management System.

1.20.10 Section 3 also explained that consultation with port stakeholders was required at the beginning and during the process and that the risk assessment needed to evolve with a number of structured meetings, the most important of which was the hazard identification meeting.

1.20.11 The port safety code 2004 was described as an assessment of the legal responsibilities under existing law applicable to the operation of New Zealand ports and harbours, and where those responsibilities lay.[20] The code stated that since the advent of port reform in the late 1980s and owing to an incomplete and fragmented statutory regime, different divisions of responsibility for harbour and marine safety functions had developed in various ports and harbours around New Zealand. The code was not mandatory and relied on voluntary compliance.

1.20.12 Under the port safety code, a regional council had the statutory responsibility for providing and regulating navigational safety in the harbours in its jurisdiction. The harbourmaster had the principal operational responsibility for the management of safety of navigation and was accountable to the regional council.

1.20.13 Under the port safety code, an appropriately qualified harbourmaster was to be on duty and contactable at all times to allow the reporting of exceptional circumstances or emergency situations, and the taking of necessary action at the scene in response to such situations.

[20] Ministry of Transport discussion paper: "Port and harbour and navigation safety management", November 2007.

1.21 Harbourmaster function at Taharoa

1.21.1 At Taharoa a licence had been issued to NZ Steel Mining to use and occupy a part of Taharoa Harbour by the Ministry of Transport, under the Harbours Act 1950.

1.21.2 At that time under the Harbours Act 1950, harbour boards had the responsibility for the commercial operation and regulatory control of New Zealand's ports and harbours. At Taharoa the only occupier of the harbour was NZ Steel Mining and the port was one of only a few considered in effect to be a private port where no harbour board existed.

1.21.3 A regulatory office of harbourmaster at the port was maintained, the harbourmaster being appointed from within the ranks of the maritime regulator of the day. Anecdotal evidence given to the Commission from previous pilots and harbourmasters was that until 2003 the harbourmaster had had little involvement and rarely visited the port. An example of this was that on 30 September 1991, a new harbourmaster had been appointed to Taharoa under the State Sector Act 1988 by Maritime NZ, a position he held until his retirement in 1999. He advised the Commission that he had never been aware that he had been officially gazetted as harbourmaster at Taharoa nor had he visited the port during his tenure.

1.21.4 In January 1988 2 of the incumbent pilots for the port were appointed under the Harbours Act as deputy harbourmasters. In practice they received little by way of practical support from the regulator and the port in general was left to run itself. One of these deputy harbourmasters was the pilot/loadmaster on board at the time of the incident.

1.21.5 In 1988, with the advent of port reform, the Port Companies Act was introduced. Generally the commercial assets and activities of the harbour boards were transferred to newly formed port companies. The harbour boards retained their regulatory function briefly until October 1989, when through the process of local government reform the existing harbour boards were abolished. Responsibility for harbour safety, together with the shareholdings of the port companies, was transferred to local authorities. In the main these were the newly formed regional councils.

1.21.6 At Taharoa there was no harbour board, so the status quo remained and the harbourmaster function was maintained by Maritime NZ. The regional council advised that this was because the council was not a port authority at Taharoa and was not obligated to undertake the function.

1.21.7 In 1991 the Resource Management Act was introduced, which replaced parts of the Harbours Act associated with land use and environmental issues. Under the Resource Management Act existing licences granted under the Harbours Act were valid until their expiry dates. At the end of 1997 Maritime NZ became aware that the operating licence for Taharoa had expired in 1993. In January 1998, NZ Steel Mining obtained a coastal permit under the Resource Management Act from Environment Waikato.

1.21.8 In 1999 the Harbours Act was repealed and regulatory functions and powers relating to navigation were transferred to the Local Government Act 1974.

1.21.9 In 1999, changes to the functions of regional councils made under the Local Government Act meant Environment Waikato became responsible for navigational safety at Taharoa. The regional council had little expertise in maritime operations and in particular the handling of large ships, so was reluctant to take over the harbourmaster function from Maritime NZ.

1.21.10 Under the Local Government Act 1974 Part 37SC, a regional council could transfer one or more of its functions, duties or powers to another public authority. Under the same provisions a regional council that transferred any function, duty or power under this section was still responsible for the exercise of that function, duty or power.

1.21.11 In July 2000, an agreement was signed between Maritime NZ and Environment Waikato that transferred the function, duty and powers that related to the management of navigational safety in the area described as Taharoa Harbour to Maritime NZ. This agreement was in accordance with sections 37SC and 37SD of the Local Government Act 1974.

1.21.12 From 2000 to the time of the incident, various Maritime NZ employees were gazetted as harbourmaster. Up until 2004, when the risk assessment process with the port safety code began, very few visits had been made to the port. Maritime NZ was represented by the deputy harbourmaster each time the Taharoa Express visited the port because he was also the pilot and loadmaster.

1.21.13 In September 2003, Maritime NZ became concerned over the increase in insurance premiums for the harbourmaster liability and risk exposure it carried at the port, including wreck removal. Consideration was given to relinquishing the role of harbourmaster at the port but it was maintained.

1.21.14 Maritime NZ also sought legal clarification on its responsibility owing to the repeal in July 2003 of section 37SC of the Local Government Act 1974 under which the transfer had been made. The repealed section was replaced by a similar provision in section 17 of the Local Government Act 2002. Maritime NZ was advised at the time that the regional council still held ultimate responsibility for navigational safety at the port.

1.21.15 In April 2007 revised legal opinion given to Maritime NZ on the transfer agreement based on case law meant that, owing to the aforementioned changes, Maritime NZ as the transferee was in fact solely responsible for the performance of navigational safety functions and associated liability at Taharoa Harbour, and had been since July 2003.

1.21.16 In January 2007, Maritime NZ revoked the warrant of the deputy harbourmaster (also pilot/loadmaster) at Taharoa. Maritime NZ had sought to increase the harbourmaster's liability insurance through RiskPool (a liability fund for local government authorities). The insurer advised that it saw a potential conflict of interest with the deputy harbourmaster being a contract employee of the port operator. A replacement deputy harbourmaster was not appointed and the function was continued by the Maritime NZ-employed harbourmaster based in Wellington and his deputy in Whangarei, who both had separate functions within Maritime NZ. The harbourmaster advised that typically either he or his deputy made a visit to the port during every second loading the ship made, the same frequency of visits that had been made before the removal of the warrant of the pilot/loadmaster. No formal record of the harbourmaster visits was kept.

1.21.17 In April 2007 a recommendation was made to and accepted by the Maritime NZ Board to withdraw from the function of harbourmaster at Taharoa. It was agreed that Environment Waikato would not take over the function until the safety management system at the port had been finalised and a suitably qualified harbourmaster appointed.

1.21.18 Under the Local Government Act 1974, a regional council could appoint harbourmasters and enforcement officers who, for the purpose of ensuring navigational safety, had general powers to give directions relating to:

- when and how a ship could enter, lie, navigate in or leave waters in a region
- the mooring, securing, placing, removing, unmooring or unsecuring of ships
- the manner of loading, discharging, securing or handling cargo.

1.21.19 A harbourmaster or enforcement officer could also, for the purpose of ensuring navigational safety or enforcing local bylaws:

- direct a ship's master to moor, unmoor, anchor, weigh anchor or move the ship
- cause a ship to be moored or unmoored.

1.21.20 A harbourmaster or regional council enforcement officer could exercise their powers if they had reasonable belief that Maritime Rules had been breached.

1.22 Development of Port Taharoa safety management system

1.22.1 In 1999 Maritime NZ reviewed its risk register, which included Taharoa, and a visit was made by Maritime NZ staff to the port to review operations. The review identified a significant risk of an accident, and thereby potential oil pollution, at Taharoa owing to the existence of a single point mooring so close to an exposed coastline and relatively large quantities of fuel oil being carried. The existing adequacy control rating was increased from 2 to 5 pending a further review of pollution measures. The rating was on a scale of 1 to 10, where 5 was an acceptable minimum level above which everything practicable was in place to mitigate the identified risk. It was noted that the ship's crew and pilot/loadmaster were experienced and the terminal had excellent operations systems in place, but at that time there was no harbourmaster gazetted for Taharoa owing to a retirement earlier in the year.

1.22.2 In 2003 there were 2 incidents involving the *Taharoa Express*:

- in March 2003. a crack was found in the intermediate propulsion shaft while the ship was loading at Taharoa. Loading was completed but the ship was eventually towed back to Japan for repairs
- in September 2003, the mooring hawser between the ship and the buoy failed. Prompt action by the pilot alerted the ship's crew and the ship avoided grounding but damaged several floating hose strings. According to a Maritime NZ report, the ship had been loading in swells in excess of 4 m prior to the incident.

1.22.3 Maritime NZ investigated both of these incidents internally. Following the hawser failure Maritime NZ and its harbourmaster held a meeting with NZ Steel Mining to review the incidents and take a wider view of the risks at the port. NZ Steel Mining was advised that as the port operator it was responsible for the ship in the port.

1.22.4 In November 2003, Maritime NZ advised Environment Waikato and NZ Steel Mining of its intention to implement nationally the port safety code, and implement the code at Taharoa through its harbourmaster function. NZ Steel Mining was also advised of its obligation under the code as the port operator to conduct a risk assessment and to develop a safety management system for its marine operations.

1.22.5 Maritime NZ recommended to NZ Steel Mining a number of service providers with port risk assessment experience who could carry out the risk assessment on its behalf. In December 2003 NZ Steel Mining advised Maritime NZ that it had sufficient expertise to carry out a risk assessment and intended to incorporate it into the company's existing hazard-reduction plan, and assumed this would satisfy Maritime NZ

1.22.6 Maritime NZ duly advised Environment Waikato that NZ Steel Mining was going to conduct its own risk assessment and develop its own risk mitigation strategies, and that this was the preferred outcome.

1.22.7 In 2003 Maritime NZ had engaged a marine consultancy called Marico Marine to assist it in authoring the risk assessment guidelines that supported the port safety code. Marico Marine had been closely involved in the implementation of the UK Port Marine Safety Code through its involvement at Milford Haven, where it had completed the world's first port operational risk assessment following the grounding of the oil tanker the Sea Empress. Marico Marine also provided the project management function for the IMO international formal safety assessment studies of bulk carriers. In January 2004 the risk assessment guidelines were complete and in February they were presented at a series of seminars to harbourmasters, regional councils and port companies.

1.22.8 On 13 February 2004 NZ Steel Mining advised Maritime NZ that it was going to review its existing risk register for Taharoa harbour and maritime operations. NZ Steel Mining extended an invitation to Maritime NZ and its harbourmaster, the load pilot and the regional council to attend the meeting on 15 March 2004 and have an input into the review of the register.

1.22.9 On 22 February there was a third incident involving the Taharoa Express. The ship lost propulsion while mooring at the buoy owing to the main engine failing to start. The ship had to deploy its anchors to avoid grounding and eventually loaded cargo 3 days later after repairs had been made to the engine.

1.22.10 On 9 March 2004, Maritime NZ sent to NZ Steel Mining copies of the draft port safety code and the risk assessment guidelines and a summary of operational issues. On the same day, Maritime NZ invited Marico Marine to assist it in the production of the safety management system for Taharoa, the first in New Zealand, which was intended to serve as an example for other ports to follow.

1.22.11 Marico Marine could not attend the 15 March meeting and emailed from the UK a draft list of hazards to Maritime NZ to use at the meeting to give "an area of focus". At the meeting NZ Steel Mining presented a list of 50 key business risks it had identified, of which 12 were safety risks. The list was given to Marico Marine for comment.

1.22.12 On 5 April 2004 Marico Marine advised Maritime NZ it had completed its review of the NZ Steel Mining risk register list of hazards. Part of the summary is quoted below:

> The risk assessment done by the NZ Steel Mining terminal is a mixture of hazards and some causes and would not give an outsider any confidence that due diligence had been reasonably discharged. Hazards that are only relevant to the commercial operations of the terminal are present, mixed in with those that affect the movement of the vessel. Overall there is no causal information whatsoever, or developed understanding that comes out of the risk assessment. The risk control cannot map to the hazard list without developed hazard and causal information, leaving the risk data open to interpretation. It is recommended Maritime NZ as harbour master conduct its own independent risk assessment related to vessel movements in the port. Even though this is a qualitative risk assessment, there needs to be some confidence that the risk control actually applied is proportionate to the risks identified.
>
> It may be worthwhile the MSA [Maritime NZ] considering getting a second terminal to have a go in order to get a second opinion, but I interpret the evidence as leaving no option but for the MSA as the harbour master to undertake a risk assessment itself.
>
> The idea that the risk is frequency + consequence = result is missing the point completely and is simply wrong. This will not provide a result that makes sense out of the risk assessment.
>
> The Taharoa risk assessment needs to have some flesh put on the bones and needs causal information to support the risk assessment scoring. The consequence information is missing almost in its entirety. The lesson learned is that you must do the risk assessment in stages and expect this to take about six weeks, even for a small terminal like Taharoa.

1.22.13 On 14 April there was another meeting between Maritime NZ, NZ Steel Mining, the pilot and the ship management company to discuss the risk assessment. At the meeting some risk control options were discussed, including the environmental parameters for the buoy. Maritime NZ also explained the process it intended to follow for the harbourmaster's risk assessment.

1.22.14 On 21 April Maritime NZ arranged a hazard identification meeting to be facilitated by Marico Marine, which was to identify the harbourmaster risks. NZ Steel Mining declined an invitation to attend, citing the short notice it had been given and because of ship loading operations at Taharoa. NZ Steel Mining also said that in its view it had just completed the process adequately through the previous meetings and that "shoehorning" the previous risk assessment into the Maritime NZ one would be more than satisfactory.

1.22.15 At the Maritime NZ hazard identification meeting that was not attended by NZ Steel Mining, 15 hazards were identified. The next day the same group had another meeting where risk control measures were proposed and considered. In interviews, members of the group recorded some disquiet over the focus of the meetings. Some thought that the Maritime NZ guidelines for risk assessments were not being followed, and some felt that the focus was more on the cost of risk controls than reducing the risk.

1.22.16 Marico Marine raised a concern that all the stakeholders needed to be collectively involved and was advised that this was not going to happen. Maritime NZ advised that it intended to take its hazards and match them to the NZ Steel Mining register and get its thoughts back on them. The Marico Marine representative questioned whether this would result in a proper risk assessment. This reservation was also shared by another Maritime NZ employee at the meeting, who had been involved in the implementation of the port safety code and the risk assessment guidelines.

1.22.17 In June Maritime NZ advised Marico Marine that it intended it to complete some of the risk assessment and the remainder would be done by Maritime NZ. Marico Marine recommended to Maritime NZ that it visit the terminal to evaluate the risk assessment and develop risk control options for the harbour safety plan as it was unhappy with the results of the hazard identification meeting. This did not happen.

1.22.18 In July the harbourmaster completed risk scoring for the hazards identified and sent them to Marico Marine. The risk assessment was called the Maritime NZ/Marico Marine risk assessment (see Appendix 5).

1.22.19 In September 2004 Marico Marine delivered a draft summary report to Maritime NZ and again raised concerns over the quality and preliminary nature of the risk assessment. Marico Marine sent separate written advice on how to proceed but its suggestions were not followed. Marico Marine advised the Commission that being aware of the organisational issues at the port it had tried at that time to move the process along.

1.22.20 The conclusion given in the report stated:

> The identification of hazards and RCOs [risk control options] is the first stage in the process of improving a management system and the observations in this report should be used that way. Further study of the detail, both of the input and the outcomes identified, may reveal aspects of the operations that as yet need addressing. Some RCOs may not fully address the risks associated with the hazards and it may be necessary to consider the hazards further. Risk assessment is a tool that should enable that process and is only a formalisation of a process that is regularly carried out informally or even subconsciously by responsible people. The formalised risk assessment technique however opens the process up to a wider circle of participants where there may be differing viewpoints that can feed back and thereby enhance it. Earlier in the document the process was referred to as dynamic which is a description intended to indicate that the ongoing regular assessment of hazards and RCOs is a necessary part of any safety management system.
>
> The first attempt to identify hazards and then assess risks is rarely conclusive. This study is no different. There may be the need for fine tuning of some of the RCOs and other hazards may be revealed. There may have been some misunderstanding of some of the issues under review and some of the hazards and RCOs may not have been ideally named. Users of the process should not be reticent in making changes. The sooner the issues are addressed the more refined will be the Safety Management System.

1.22.21 In November 2004 Maritime NZ sent a copy of the draft risk assessment provided by Marico Marine to NZ Steel Mining, advising that many of the identified risks mirrored those in the NZ Steel Mining register. Also most of the risk controls were already in place or under development by NZ Steel Mining and it was the intention to draw on both risk assessments in preparing the safety management system for the port.

1.22.22 The draft risk assessment was also sent to a company called Saros Limited (Saros), contracted by Maritime NZ to develop the safety management system. Saros advised the Commission it was aware at the time of a number of contentious issues around the risk assessment and in particular the single buoy mooring; however, the remit given was not to revisit the risk assessment, so it didn't.

1.22.23 In December 2004 Marico Marine delivered to Maritime NZ another draft summary risk assessment. In this second draft the conclusion stated:

> As this is a summary report in draft, conclusions will need to be reached from feedback from the stakeholding organisations.

1.22.24 A final draft summary risk assessment was issued in January 2005. It concluded the following:

> 1. The Taharoa Express operation has a number of hazards that provide a risk profile that should not be underestimated.
> 2. Although this risk assessment has had limited input from wider stakeholders, a significant number of risk control options are available. These options have been developed to address more than one area of significant risk in parallel, making them cost effective.
> 3. The loss of mooring securing arrangement has been identified as the highest risk. An example of common practice for back-up arrangements has been included in this section on risk control options.
> 4. The top end of the hazard list should be considered with equal priority, given the limitations of an assessment based on expert judgement, with a limited number of persons with operational input from Taharoa.
> 5. As is the case in a number of places in New Zealand a number of organisational issues associated with the role of the Harbourmaster are apparent at Taharoa. Addressing these is already recognised by the study team as key to introducing a cost effective and working safety management system.
> 6. The risk assessment should be reviewed by all stakeholders and added to as the safety management system for marine operations is introduced.
> 7. The safety plan as required by the NZ Port and Harbour Marine Safety Code should now be developed by ongoing consultation.

1.22.25 Apart from the amendments to the conclusions sections of the 3 draft summary reports submitted by Marico Marine, the body of the report remained the same.

1.22.26 At the end of 2004 Saros was not in a position to complete the safety management system, so the safety management system was taken back in-house by Maritime NZ in early 2005, which had engaged a full-time maritime risk manager, whose role included the review of risk assessments and safety management systems submitted to Maritime NZ from the other ports that were applying the port safety code.

1.22.27 At the time of the incident the safety management system manual was still in draft form. The fifth and latest version of the port safety code had been issued in January 2007.

1.22.28 The draft safety management system manual referred to a consolidated risk register that combined the Maritime NZ/Marico Marine and NZ Steel Mining risk assessments. The manual explained that although the risks had been assessed in somewhat different ways and there might not be direct equivalence of the risk scores, the ranking of risk and the philosophy for managing risk at the different levels within each system were essentially the same.

1.22.29 The risk control measures and possible additions developed by both Maritime NZ and NZ Steel Mining were then mapped to the consolidated register in a bow-tie matrix. This was illustrated in the safety management system manual (see Figure 23).

1.22.30 The safety management system section 4.4.3 described the 2 approaches to the risk assessment for Port Taharoa to produce the consolidated risk assessment. The methodology for the overview risk assessment is quoted in part below:

> Marico Marine was subsequently engaged by Maritime NZ to facilitate the development of an "overview risk assessment" for the Port of Taharoa. Given the development of the NZ Port and Harbour Safety Code, the aim of this assessment was to apply the methodology as set out in the Guidelines to the port operation. A series of meetings involving Maritime NZ staff, including the harbourmaster, were held in May 2004 to identify and assess the risks associated with the Taharoa operation and to develop potential risk control options. The hazard identification and risk assessment were documented using the HAZMAN© software.

1.22.31 The 15 identified hazards in the Maritime NZ/Marico Marine risk assessment relating to the movement of ships at Taharoa detailed the most likely and the worst credible consequences of each hazard on people, environment, property and stakeholders. The Maritime NZ/Marico Marine risk assessment that appeared in the fifth draft of the safety management system manual published in January 2007 comprised the same hazards and overall risk scores as had been assessed in June 2004. An additional hazard was added that comprised 9 risks from the NZ Steel Mining risk assessment not allocated to the Maritime NZ/Marico Marine risk assessment.

1.22.32 Risks from both assessments were ranked in order of their overall risk score in descending order. This formed the basis for the priority in which the hazards were to be addressed. Both risk assessments used a risk score of 5 as the so-called ALARP (as low as reasonably practicable) level. The risk scoring and tolerability table copied from the draft safety management system manual is shown in Figure 24.

1.22.33 The Maritime NZ register contained 5 hazards at the ALARP level or higher, as detailed in Appendix 5.

1.22.34 Hazard number 10 in the Maritime NZ list was the export vessel loss of stability margin on loading owing to inadequate de-watering procedures and unplanned rapid disconnection from the mooring.

1.22.35 Hazard 10 focused on the export ship and the International Load Line Convention, which dictated that the ship should not leave port without meeting stability and draft criteria, a legal requirement completed normally when a ship clears port. The risk assessment noted that cape-size vessels, of which the Taharoa Express was one, rarely suffered any lateral stability problems owing to their width-to-depth ratio, which was larger than on smaller ships. The risk assessment noted, however, the legal implications of the ship having to leave port at short notice owing to weather.

1.22.36 The most likely outcome of the hazard was identified as inconsequential for a cape-size ship, notwithstanding the legal requirements of the IMO Load Line Convention.

1.22.37 The worst credible outcome of the hazard was identified as a sloshing or cargo movement problem aboard the export ship, most likely with the ship on passage and well away from the terminal. The risk assessment also stated that this could lead to internal structural failure and total loss of the ship, and that the responsibility for stability was primarily with the ship's master, but aspects of international conventions could implicate the port in the decision for the ship to sail.

1.22.38 Hazard number 10 was ranked 15 out of 15. The overall risk score for that hazard in both the original Maritime NZ risk assessment and the latest version of the safety management system manual was 1.66, thereby identifying it as a low risk.

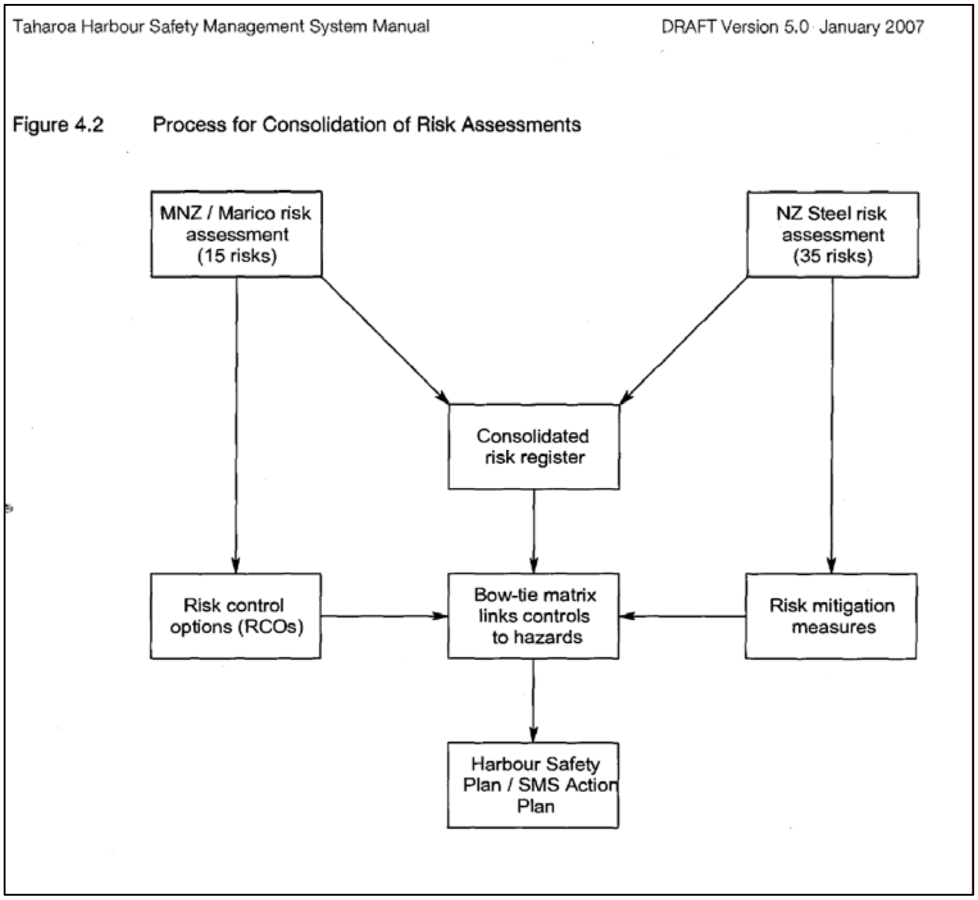


Figure 23
Safety management system consolidated risk register

1.22.39 The Maritime NZ/Marico Marine risk assessment summary report, issue one identified one risk control option matched to hazard number 10. That was to extend the harbour limit. If a ship had to leave the single buoy mooring at short notice owing to the weather while loaded deeper than its allowable draught, it was considered that it would be unwise to anchor and continue de-watering within the harbour limit at the time because of the close proximity to the shore.

1.22.40 Matched to this risk were 2 NZ Steel Mining documents from its register. They were S03474 “failure to follow the loading plan” with a risk score of 3, low risk and S03475 “improper loading plan including de-watering’ with a risk score of 6, heightened risk.

1.22.41 Two mitigation measures were identified in the NZ Steel Mining register matched to hazard 10: the split pattern of loading to prevent overloading of the holds, and 6 hours of de-watering at the end of loading to ensure a safe draught before departure. The measures identified no risk related to the effects of having free water above the cargo on departure, sloshing or the effect of free water on the stability of a ship.

1.22.42 Hazards 1, 2 and 3 of the Maritime NZ/Marico Marine risk assessment summary report covered equipment failure on the ship and grounding. These were ranked highest in terms of risk data scores. The worst credible outcome in part noted the outcome to be “grounding in heavy seas with loss of hull integrity, rapid structural failure (bulk carrier currently employed built in the middle of period of design optimisation)”. The optimisation period was generally considered to affect bulk carriers built between 1988 and 1999. Optimisation was the wholesale removal of steel mass from large bulk carriers to economise design, save build costs and increase the carrying capacity of the ship. The global strength of the ship was reduced and a more flexible structure resulted. The process was an underlying cause of a significant number of structural failures, and it included a reduction in bulkhead strength of this ship type such that bulk carriers could withstand flooding only at the assumed draught in the assessed damaged condition (i.e. at only about 40% of the bulkhead depth covered). This led to the adoption by IMO of the amendments to SOLAS Chapter XII and the requirement to strengthen the foremost bulkhead in existing bulk carriers to be able to withstand total flooding. The *Taharoa Express* was built during this period.

Risk Score	Methodology in Guidelines (Maritime NZ)		NZ Steel Mining Methodology
	Description	Suggested actions	Comments
9& 10	High risk	Risks at this level require immediate attention and if they cannot be reduced to ALARP, the activity should cease.	For safety and environmental risks, the question should be asked; "should the operation or activity be stopped until after the risk has been reduced to 7 or less?"
7& 8	Significant risk	A level where existing risk control is automatically reviewed and suggestions made where additional risk control could be applied if appropriate. New controls identified to manage this level should be in place within 2 years.	These risks should be reduced to ALARP
6	Heightened risk		
4& 5	ALARP	A level at which risk controls in place are reviewed and kept under review in the SMS [safety management system].	Risks at this level would be considered tolerable, and not require any further reduction or control
2& 3	Low risk	A level where operational safety is assumed.	
0& 1	Negligible risk	A level where operational safety is unaffected.	Not used

Figure 24
Risk scoring and tolerability table

1.22.43 After the initial risk register had been made, a number of risk controls were put into place in the port and on the ship mitigating those risks identified in the original register. Despite the implementation of these controls, the overall risk scores for the hazards remained the same and formal evaluations of their effects had not been completed by Maritime NZ.

1.22.44 The incident happened more than 3 years after the initial hazard identification meeting conducted between Maritime NZ and Marico Marine. Version V of the draft Taharoa harbour safety management system manual was current at the time of the incident. The draft showed that no new risks had been identified by Maritime NZ risk assessment since the original meeting in April 2004 and no new risk controls had been identified. During the period 2005 to 2007 a number of new risk controls were implemented:

- a trainee pilot/loadmaster was employed by the pilotage provider and was in training at the time of this incident
- the load cell on the hawser was commissioned
- the vessel position indicator/monitor was commissioned
- weather monitoring, trend analysis and forecasting for the purposes of load planning were improved.

Although the new risk controls had been implemented, the overall risk scores for the hazards had not been reassessed and remained unchanged.

1.22.45 The port safety code stated that where Maritime NZ was required to undertake a risk assessment and develop safety management documentation, it would seek independent peer review to confirm compliance. The draft safety management system manual made reference to this and stated that the manual was to be peer reviewed by an independent and suitably qualified and experienced body to confirm compliance. At the time of the incident a review had not been undertaken, but in January 2008 Lloyds Register conducted an independent review of the port safety management system.

1.22.46 The Lloyds report made a number of recommendations on both of the risk assessments in the safety management system. Regarding the consolidated risk register the report stated:

> The SMS [safety management system] contains a consolidated risk register incorporating NZS [NZ Steel Mining] risk register (April 2004) and MNZ [Maritime NZ] risk register (May 2004). In reviewing both risk registers, it was evident that there are numerous similarities in the identification of hazards, however the methodologies in conducting the RA's [risk assessments] were based on different approaches.
>
> The combined RA summary format in the SMS may not be easily understood by users of the SMS manual, as would be the case if a single RA was presented. This is further complicated by differing calculations used to establish the individual risk scores.
>
> Recommendation 13:
>
> Formalise both RA's into one when the next update is required to be submitted to MNZ by NZS. The updated RA should be completed by NZS with MNZ being the regulatory overviewer.

2 Analysis

2.1 General comment

2.1.1 The *Taharoa Express*, like thousands of other ships trading worldwide, was governed by an intricate and often complex set of rules and regulations. IMO set some as international standards for the high seas between national territories, and others for various Flag and Port States to incorporate into their national statutes. The aim was to achieve some sort of consistency of standards, making it easier for ships trading internationally.

2.1.2 Increasingly, safety management systems are being adopted by transport systems as a means of achieving safe and consistent standards across an industry. For international or SOLAS ships, the ISM Code was adopted by IMO in 1993 and became mandatory for most ships in 1998. Under the ISM Code ship owners and operators are required to develop an ISM system that says how they are going to manage the day-to-day operation of one or more ships safely. Each ship must in turn develop a system to say how the master is going to manage the day-to-day operation of their ship. The 2 systems must be compatible and include how compliance with the relevant rules and regulations and interoperability with other stakeholders (port operators for example) are going to be achieved.

2.1.3 Transiting a port facility is arguably the time of the heaviest workload for a ship's crew, and carries an increased level of risk. Just as an operator's safety management system should be an integral part of the shipboard system and vice versa, it makes sense for port operators to have safety management systems in place that integrate with those required of ships and ship operators. Some Administrations around the world have started to adopt the safety management system concept for ports, and the New Zealand system was a developing example of that.

2.1.4 The risk assessment guidelines under the port safety code provided guidance to those responsible for navigational safety within the harbour limits. In most cases cargo operations would be the responsibility of the port operator through their obligations under the Maritime Transport Act and health and safety legislation. At Taharoa, because of the potential impact of the loading method on the safe navigation of and decision to sail the ship, the harbourmaster's risk assessment also had to consider hazards resulting from loading operations for it to be effective.

2.1.5 Specialised ships operating out of dedicated port facilities are not an unusual concept in the maritime industry. Almost all roll-on-roll-off operations fall into this category, where the terminals are designed around the ship or vice versa. The *Taharoa Express* and Port Taharoa were no exception. The loading operation was unique, and the ship had been specifically modified for that operation; each relied exclusively on the other. Similarly, the safety management system for the ship and that for the port should have been closely aligned. Because of that close relationship there would inevitably have been an overlap in responsibilities. These responsibilities needed to be defined clearly in the respective safety management systems.

2.1.6 The importance of proper loading of bulk carriers was recognised by IMO and reflected in its bulk loading code. Not only have these codes been enacted into New Zealand law through Maritime Rules, but the Local Government Act has given regional councils through their appointed harbourmasters the mechanism to intervene if Maritime Rules are not adhered to during a bulk loading operation, or if there is a resulting risk to life, property or the environment.

2.1.7 For the *Taharoa Express*, there were indications that within the various elements of the wider system there was a tendency to ignore problems facing people in other parts of the system and for people to retreat to their organisational and occupational niches and deny any broader responsibilities. This was evidenced at 3 levels:

- on board the *Taharoa Express*, between departments and between cultural groups
- at management level between the ship, ship owner and ship operator

- at a higher level, even though there were regular meetings between all the stakeholders at the port, a satisfactory level of integration of the various safe management systems did not result.

These points are discussed in more detail below.

2.2 Steel repairs in Zhoushan

2.2.1 The *Taharoa Express* had been converted from a conventional bulk carrier, and the main structure of the ship was similar to that of conventional bulk carriers. The construction of the overflow recess within the lower stools and corrugated bulkheads was, however, unique to this type of ship. The integrity of the overflow recesses was critical to the safe operation of the ship.

2.2.2 The responsibility for ensuring work on critical systems was completed to a satisfactory standard was shared across several groups, but the prime responsibility lay with the ship owner and its servants, including the ship management company and the crew on board. The shipyard had responsibility for conducting repairs in a diligent manner, but there were obvious quality control issues with the yard's work. This was evidenced not only by the unsealed cope holes in the overflow recess, but in the poor standard of repairs in other areas observed during the investigation. The shipboard staff were aware of the quality control issues, which should have served as a warning to check and sign off work more diligently.

2.2.3 Class surveyors had a duty to ensure the standard of the repairs was up to Class standards, and in this case there was also a duty to the Flag State of Panama.

2.2.4 The ship's safety management system under the ISM Code did not identify the de-canting and de-watering plant as being a critical system on board. No pressure testing was requested by Class NK surveyors, the ship's supervising superintendents or ship's officers who were familiar with the ship's systems. A simple pressure test such as filling the space with water would have made the unsealed cope holes apparent.

2.2.5 Communications between the ship and shipyard were complicated owing to language difficulties. Had a more rigorous repair, inspection and test regime been documented at the outset, these communication difficulties could have been mitigated, particularly as written communication was found to have been the most effective form of communication.

2.2.6 It would have been more prudent to have the ship's regular superintendent present for the dry dock as he was most familiar with the *Taharoa Express*, which was a specialised ship among the general bulk fleet that the company managed.

2.3 Flooding the duct keel and understanding the problem

2.3.1 The incident demonstrated the vulnerability of the ship's systems from a flooded duct keel. The ship's ballast, de-canting and de-watering systems were immobilised owing to water ingress to the valve control equipment located in the duct keel. Once the duct keel was flooded, local emergency operation of the valves was impossible and the systems remained inoperable.

2.3.2 The operation of these systems was critical to the safe operation of the *Taharoa Express* when loading at Taharoa, an unsheltered port that it may have had to leave at short notice. None of those on board or who managed the ship, or regulated and operated the port had evaluated the risk to the ship of such an event.

2.3.3 Failure mode effect analysis is a process to assist in identifying critical components and thus contributes to hazard identification and risk assessment. In the duct keel flooding, for example, the effect was the malfunction of both the de-canting and ballast valves, which meant ship staff could not de-water or adjust ballast at a critical time while vulnerable to the weather.

2.3.4 Through failure mode effect analysis, modifications can be made or steps taken to mitigate risks. Using this example, it could have been accepted that the duct keel was going to flood from time to time, so the electronics could have been moved out of the duct keel so that a critical system was not affected, or alternatively the loss of the valve system could have been accepted but an alternative means of de-canting and de-watering provided. In this manner all systems on the ship could have been scrutinised under failure mode before an actual failure occurred.

2.3.5 The existing system for pumping the duct keel allowed the use of a large-capacity pump if required; the pumping rate was limited by the relatively small bore of the single bilge suction pipe. The system had a potential single point of failure. In the incident, an incorrectly fitted strum box allowed a plastic cap to block the suction pipe end partially, illustrating the above point.

2.3.6 Owing to the duct keel alarm being activated regularly on the voyage to Taharoa, it is possible that the engine room crew became accustomed to the alarm condition, so when the alarm sounded during the loading operation they assumed that the water was from the crack in number 6 cargo hold, and of a manageable proportion not requiring immediate attention.

2.3.7 There have been numerous accidents and incidents caused by blocking or ignoring, or in this case giving low priority to, alarms that sound frequently, particularly nuisance or spurious alarms. Alarms are defences in the system and require prompt investigation each time they occur. They are usually a signal that something has happened, or is about to happen.

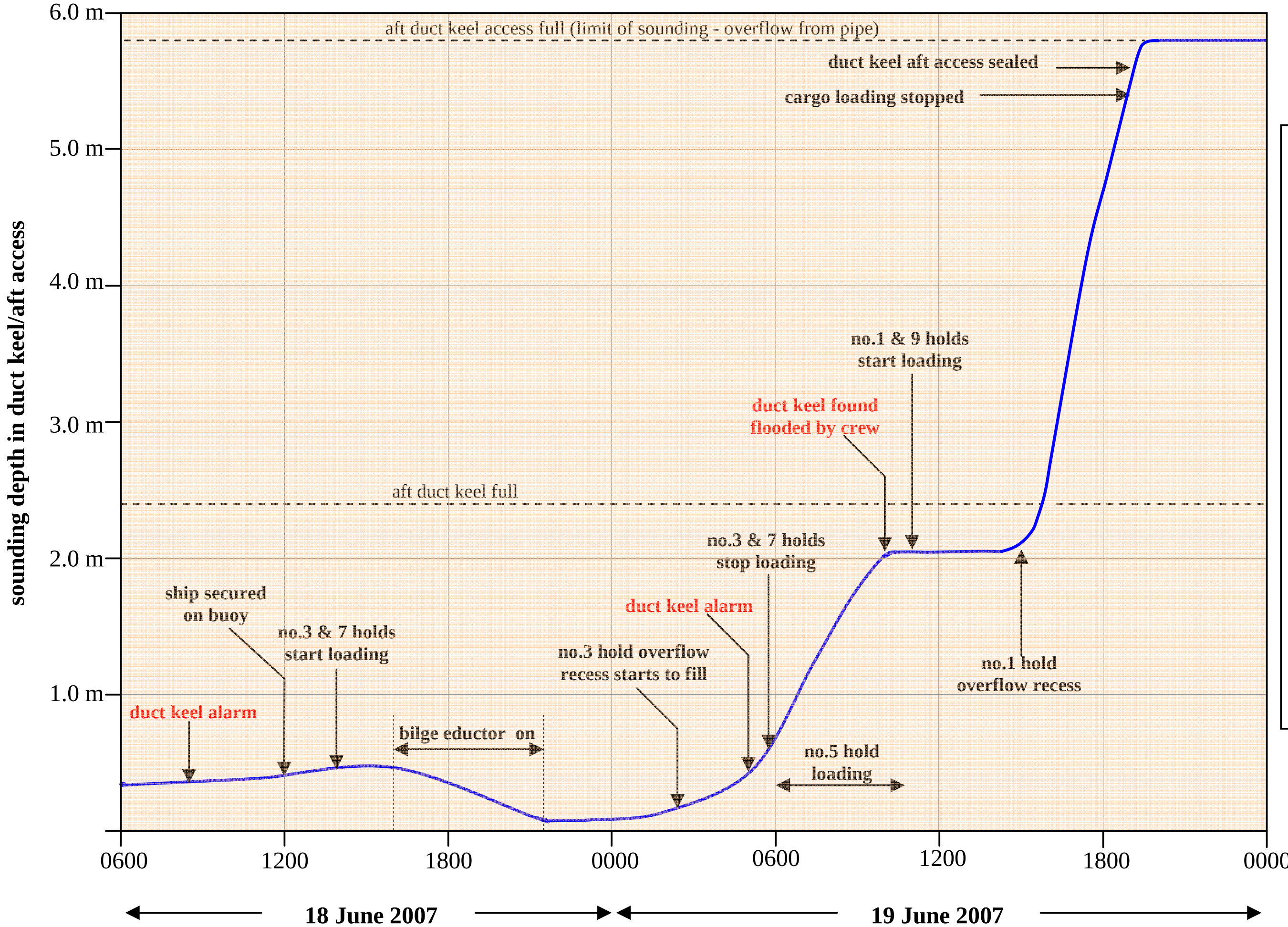
2.3.8 Figure 25 shows the timeline of the duct keel flooding to the suspension of cargo loading. It shows the cues that were missed by the crew on the ship and the consequences of continuing to load the ship without identifying the root cause of the problem.

2.3.9 On board the *Taharoa Express* the first mate was the only person who pumped the duct keel, so when he was busy on other tasks the job did not get done. The engine room crew were under the impression that their responsibility was to report the alarm only. It was routine for the crew to report a duct keel bilge alarm then not monitor the water level regardless of whether or not the first mate had checked the level himself or started the eductor. An effective and cohesive crew would have had a system that ensured resolution, or at least understanding of the problem regardless of the circumstances. Had the engine room crew been aware that the duct keel bilge alarm had activated less than 12 hours after the eductor had been turned off, they could have given the alarm a higher priority.

2.3.10 The actions of the crew in attending to the duct keel alarm were an indication of a hierarchal (tendency to defer responsibility upwards) management system on board. This became evident during interviews following the incident, where the cultural differences between the Filipino officers and crew and the Japanese senior officers were obvious. This hierarchal system of dealing with problems on board extended to the relationship between the ship- and shore-based management. When the superintendent was on board, operational decisions were normally deferred to him, and he in turn deferred them to his superiors in Japan.

2.3.11 Even when the duct keel flooding was realised, the extent of the problem was not made clear to the trainee loadmaster on duty at the time. All he was told was that there was a problem with valves in number 5 cargo hold. Unaware of the complete picture, neither he nor the loadmaster was in a position to offer advice to the ship and suspend the loading operation

2.3.12 The decision to suspend cargo operations was taken too late. The decision-making process was hampered by the need to seek a decision from the ship management company in Japan, and time was lost trying to contact people who were not immediately available. The master and his senior officers were best placed to assess the unfolding situation. Ultimate responsibility rested with the master and he had the authority to stop loading.



Timeline of flooding

18 June 2008

0800 duct keel alarm activated
1200 ship secured to buoy
1400 start loading 3 and 7 holds
1600 duct keel eductor on
2100 duct keel eductor off

19 June 2008

0230 no.3 hold starts to overflow
0500 duct keel alarm activated
0520 no.3 and 7 holds 1st load complete
0730 no.5 hold start loading
1000 duct keel found flooded by crew
1100 no.5 hold stop loading
1120 no.1 and 9 holds start loading
1600 no.1 hold starts to overflow
1630 duct keel full aft
1900 cargo loading suspended
1930 duct keel aft access sealed

Figure 25
Timeline of duct keel flooding and key events

2.3.13 Had loading been suspended when the flooded duct keel was discovered at 1000, the emergency pumping measures could have been deployed sooner because it would not have been necessary to seal the aft access to the duct keel. The rate of water removal using the emergency pumping measures indicates that the duct keel would have been accessible before the ship had to depart the buoy, allowing ballast de-canting and de-watering systems to be reinstated using the emergency hydraulic pump for valve operation and reducing the risk to the ship when it departed.

2.3.14 Importantly, if the loading had stopped at 1000, numbers 1 and 9 holds would still have been empty and the effects of free surface on stability and a cargo shift reduced.

2.3.15 A simple test of the water in the duct keel either by taste or using the ship's hydrometer would have differentiated between it being seawater from number 6 cargo hold, as suspected, or fresh water, which would have indicated it was from the loading process.

2.4 The decision to sail

2.4.1 The interruptions to the loading process on the incident voyage illustrate that the loading sequence was prone to interruption for a variety of reasons. Minor problems to the plant ashore could potentially influence the load and ballast sequences. The consequences of such breakdowns were categorised as a commercial risk to the port operator, however this incident shows that, if not managed correctly, such interruptions could have more serious consequences for the ship when other factors such as inclement weather or shipboard problems occurred concurrently.

2.4.2 Had the *Taharoa Express* stayed at the single buoy mooring during the forecast period of severe weather, the operating parameters for the buoy would have been exceeded. The risk of the ship breaking the mooring line and running aground owing to the close proximity of the single buoy mooring to the shore was high. To do so would also have been in breach of the harbourmaster's directives.

2.4.3 There was no alternative safe mooring provided for the ship within the port. Although the ship could have anchored within port limits and still technically been in port, the port offered no safe haven from the forecast weather. To remain in port limits in the forecast conditions would still have put the ship at a considerable risk of dragging its anchors and grounding.

2.4.4 Both the master of the *Taharoa Express* and the harbourmaster for the port were faced with a difficult situation. The ship clearly could not stay on the single buoy mooring, and the risk associated with anchoring on a lee shore within the port was high.

2.4.5 Harbourmasters have a general conservancy for the safety of a harbour but at no time should they knowingly invite a ship into danger. The *Taharoa Express* was at risk sailing with a part cargo of iron sand and a significant amount of free water in the cargo holds, including the partially filled number 6 hold.

2.4.6 On reflection the decision was made easy, because those involved in loading and sailing the ship did not appreciate the level of risk to the ship. In the past the ship had been at the buoy in inclement weather; so too had it been forced to sail with free water in the holds into heavy weather. In the entire history of the operation there had been no recorded problems encountered with cargo shift or sloshing damage.

2.4.7 One option available to the master was to sail the vessel off the coast and ride out the predicted weather hove-to bow to the sea, keeping the ship movement to a minimum and thereby reducing the chance of damage by sloshing and reducing the chance of cargo shift. In saying that, however, the weather was forecast to be severe for a number of days, and at the time of sailing the master still did not know the cause of the duct keel flooding.

2.5 Voyage from Taharoa to Tasman Bay

2.5.1 Nothing was treated as untoward when the *Taharoa Express* departed Taharoa. In all respects, it was simply treated as another voyage to Tasman Bay. Given the condition of the ship it would have been prudent to have made a more accurate assessment of stability to gauge the effect of free surface, and for the master to have issued specific instructions regarding the voyage.

2.5.2 None of the night orders issued by the master on 21 June related specifically to the condition of the ship and the potential dangers to which it was exposed by virtue of the amount of free water on board. No instructions were given to officers of the watch to notify the master of any changes to the ship's condition. The master made no reference to the forecast deterioration in the weather and issued no specific instructions on the circumstances under which he should be called.

2.5.3 The master did not attend the bridge after he had written his night orders at 1700. Given the circumstances it is unusual that he did not feel the need to visit the bridge to check on the ship's handling and the weather personally if he had perceived correctly the level of risk to which the ship was exposed.

2.5.4 Essentially everyone retired to catch up on sleep, leaving the most junior officer in charge on the bridge until midnight whereupon he was relieved by the second mate. Under the command of these 2 officers the ship followed its intended course at full speed until the ship developed a severe list at 0150 the next day. At no point during that period, despite the deteriorating weather, the reported unusual motion of the ship owing to free surface effects and the increasing list did either officer call the master to tell him that they had any concerns.

2.5.5 The performance of the crew, and specifically the lack of interaction between departments on board during the voyage, is consistent with that displayed when the duct keel flooded. There was no interaction between the crew to achieve a common goal; instead each was looking after their own perceived job, with little thought to how each of their actions could affect the performance of others. There was no evidence of a healthy challenge-and-response culture on board; conversely, there looked to be a significant power-distance relationship between senior officers and crew, the same power-distance relationship that existed between the senior officers on board and the ship management company ashore.

Cargo shift mechanism

2.5.6 Those associated with the loading operation were all of the opinion that the Taharoa iron sand was stable once it had settled to the bottom of the hold. These opinions were not based on any understanding of the technical properties of the sand, but more on historical observation; there had never been a recorded case of the sand shifting in transit, but then the circumstances on the incident voyage had in all probability never been encountered either.

2.5.7 IMO data on bulk carrier casualties shows that losses of cape-size bulk carriers have been mainly attributed to structural failure of the ships owing to flooding of one or more holds leading to a loss in stability margin and the ships sinking. In general it is considered that these size ships have a good reserve of stability when loaded correctly. Normally they have a large GM, making them relatively "stiff", and the *Taharoa Express* was no different.

2.5.8 The nature of cargo shifts in bulk carriers has been recognised as being complex, and as such the IMO regulations have been developed from research and studies of casualties over time. Some of the complexities involved in evaluating a particular cargo on a given voyage include ship stability characteristics, encountered sea states, voyage lengths and hold geometry. The NZ Steel Mining-commissioned report[21] gives an insight into the difficulties of trying to assess the properties of a wet cargo under a single set of conditions. Analysing such data on a case-by-case basis might be practicable, but to write a set of standards and guidelines to cover all

[21] ibid section 1.13.1.

eventualities would be difficult. That is why generic IMO data and guidance are given in broad terms and should be viewed as absolute minimum standards to achieve. Ship and port operators must assess their own operations in much more detail, and should share any data learned with IMO for dissemination to the wider maritime community.

2.5.9 The NZ Steel Mining report concluded that the shift of sand across to starboard in all holds was a progressive one caused by entrainment of the sand owing to wave action, aided by the starboard list with which the ship sailed from Taharoa. The tests conducted supported the view that this was likely the main mechanism for the shift, but the tests did not replicate all the conditions prevailing at the time to draw the conclusion that it was the only mechanism.

2.5.10 The tests did not replicate all the degrees of motion to which the sand and water combination in each hold would have been subjected. For example, the sloshing analysis determined that the sway motion contributed most to any sloshing. The same analysis identified that local pressure gradients owing to sloshing acting on the sand could result in displacement of the sand.

2.5.11 While the Taharoa iron sand might not have easily liquefied even when its TML was exceeded, other mechanisms causing it to shift needed to be considered.

2.5.12 The exact timing and rate of change of the developing list were difficult to determine. No one else was monitoring the progress of the ship and the state of the cargo on the voyage to Tasman Bay; the testimony of the second and third mates was all that could be relied on. The third mate thought that the list had progressively increased to 5° by the time he handed the watch to the second mate at midnight. This would be consistent with the theory of a cumulative shift of sand owing to wash action across the surface of the sand.

2.5.13 The second mate said the list had developed to 15° by the time he took on the watch at midnight. Evident during interviews was an underlying fear of possible retribution for their actions having contributed to the incident. The answer probably lies somewhere between the 2 estimates, but as the ship was essentially head to sea for all but the last hour before midnight, it is more likely the rate of change in list accelerated through the midnight period when the planned track of the ship progressively put the developing sea and swell more on the beam, increasing the roll and sway motion.

2.5.14 The NZ Steel Mining report showed that a shift of sand owing to entrainment was largely reliant on the surface of the sand being exposed during internal wave action. With the different levels of free water on top of the sand in each hold, and as the list increased, other sand in other holds would have become exposed, thereby progressively increasing the rate of change in the list. Together with the sea and swell being placed on the beam with the resultant increase in roll and sway, this could have been the only mechanism for the cargo shift, with the final roll that awoke the harbour pilot at 0150 in the morning merely being the ship responding to a larger wave that would normally be encountered periodically.

2.5.15 What could not be ruled out, however, was an en masse shift of sand in one or more cargo holds. For example, if the ship were rolling 20° about a 10° axis to starboard, the tank top would have been reaching an angle of 30°; this, combined with a wet cargo base and local pressure gradient on the sand caused by sloshing, could have been sufficient to cause the cargo to slide. None of the holds was loaded to its normal depth and therefore the cargo would not have received as much support from the hold sides as when fully loaded.

2.5.16 On passage under the action of the ship's motion and gravity, water from the top of the cargo would tend to drain towards the bottom of the cargo. Removal of this water from the base of the cargo using the ship's de-watering system would normally reduce the build-up of pore pressure between the cargo particles in the base of the hold. On passage this would reduce the possibility of liquefaction or a cargo slide either in part or en masse across the base of the hold. However, when the ship departed Taharoa on the incident voyage, the de-watering system was not operational.

2.5.17 The second report commissioned by NZ Steel Mining[22] acknowledged that liquefaction at the surface of the iron sand was possible with supernatant water remaining above the cargo; this being due to water pressure on the surface of the sand increasing the pore water pressure under the surface of the sand. To what depth this potential liquefaction could occur was not estimated, but was thought would be directly related to the depth of supernatant water above. The report also mentioned resistance to liquefaction at the base of the cargo owing to decreasing pore water pressure; this on the assumption that water was being removed from the base of the cargo by the de-watering process, but the de-watering equipment on this occasion was not operational.

2.5.18 The initial starboard list when sailing from Taharoa was a likely factor in initiating the cargo shift. Ships often roll unevenly about their axis for a number of reasons, including the encounter period and direction of the waves, and constant wind on the beam. It is still possible for a shift in cargo to have occurred even if the ship departed Taharoa upright with the ballast system being inoperable.

2.5.19 The circumstances of this incident show that the way a ship is handled at sea where water is sloshing above the cargo can play a big part in reducing the likelihood of a cargo shift, depending on the characteristics of the cargo.

2.5.20 Had the ship continued on its course and speed from 0150 hours, it is highly likely that the list would have continued to increase as further wash action on the sand and possible en masse shift of cargo occurred. The action taken at 0150 hours temporarily reduced the motion of the ship and reduced the rate of cargo movement, but the subsequent controlled course alterations as the ship sought shelter in Tasman Bay still resulted in the ship's list increasing another 5° to a maximum of 22°, before the ship reached its safe haven.

Sloshing and structural damage

2.5.21 Work on formal safety assessments for bulk carriers completed for IMO identified shell-side failure as a significant issue in relation to losses. The formal safety assessments identified that in larger ships the flooding of a single hull compartment should not lead to a ship sinking. Studies concluded that ships were lost through subsequent failure of internal bulkheads within the ships owing to the pressure head of the water and dynamic forces of the water under the ships' motion. These dynamic forces are referred to as sloshing forces and can lead to structural failure with resultant flooding of other compartments, and eventual loss of the ship. In most circumstances this has occurred quickly and in some cases with the loss of all crew.

2.5.22 Formal safety assessments resulted in IMO adopting SOLAS Chapter XII, which set out the requirements for improved strength of existing and new bulk carriers. The requirements for existing ships were that only the most forward hold was to be capable of withstanding total flooding or the hold was at least to be double-skinned to reduce the risk of flooding. For new ships, all holds were required to withstand total flooding.

2.5.23 The work completed by IMO highlighted the potential dangers of the effects of sloshing from water that flooded into cargo holds and from slack water in ballast holds. On the *Taharoa Express*, the integrity of the hull was not breached but the ship sailed with a considerable amount of free water above the cargo and in the ballast hold. This free water generated considerable sloshing forces within the ship's holds, more than the ship had been designed to withstand.

2.5.24 The purpose of commissioning a report on the stability and sloshing effects on the *Taharoa Express* was to determine whether its structural design parameters had been exceeded and to evaluate the level of risk of the ship and its crew during the incident.

2.5.25 The sloshing report considered the free water in each of the ship's holds and concluded that the holds susceptible to the highest sloshing forces were numbers 5 and 6, so the investigation

[22] ibid section 1.13.16.

focused on these 2 holds. The highest forces were found to act on the longitudinal structure (the sides of the cargo hold) and were caused by sway motion.

2.5.26 The design parameters for the ship were exceeded on the voyage to Tasman Bay. This was shown by the modelling of the sloshing forces and by the local damage sustained in the areas of the ship identified as being at risk in the sloshing analysis. The ship's main structure did not fail in a catastrophic way during the voyage, but sustained local impact damage that could eventually lead to major structural failure if left unchecked.

2.5.27 It could not be determined with certainty when the uniform buckling of the corrugated bulkhead in number 1 hold took place, because the ship had made one more loading at Taharoa since the incident voyage before it was noticed. The shear forces and bending moments on the hull by way of the aft bulkhead of number 1 hold were 80% of allowable limits as calculated on the ship stability program. The buckling being symmetrical along the bulkhead and initiating at the termination of the old and new steel replaced in dry dock suggests the damage was more consistent with dynamic forces of the weight of the cargo and supernatant water, possibly exacerbated by sloshing of the supernatant water in the hold on the incident voyage. The termination between the old and new steel is likely to have created a weak point for deformation to occur. The design of the double-skin and attachment to the corrugated bulkhead may have also contributed to discontinuity of the framing and its ability to transfer stresses into the hull.

2.5.28 Similarly the exact time of the initiation of the cracks in the side frames could not be determined. The physical appearance of the cracks suggests they existed before the repair period in Zhoushan. This would indicate that parts of the ship's structure were over-stressed before the incident voyage under normal loading conditions. The fitting of the tripping brackets to number 1 corrugated bulkhead post incident by the ship management company with the tacit agreement of Class NK highlights typical remedial measures taken to try to overcome structural problems in older ships that have been subject to fatigue stresses and a reduction in scantlings over time.

2.5.29 The construction of the double-skin highlights one difficulty facing surveyors when inspecting ageing bulk carriers where minimal consideration was given for access and close-up inspection was not required. The fact that such cracks went undetected for a considerable time and probably existed before the intermediate survey prior to the incident voyage highlights the risks faced by ageing bulk carriers.

2.5.30 Number 6 ballast hold suffered local damage in the top-side and hopper-side tanks, areas identified as highly loaded by sloshing forces on the incident voyage. The buckling of the plate in the emergency fire pump access behind number 6 hold, although not discovered until after the incident voyage, was in the opinion of Class NK caused by sloshing during the incident voyage, a contrary opinion to that of the ship management company. Although not a part of the structural strength of the corrugated bulkhead, the plate's failure would have made number 6 hold common with the duct keel; that is any water in the hold would cause the duct keel to flood again.

The investigation has highlighted structural faults owing to poor workmanship during the repair period in Zhoushan and others owing to the incident voyage conditions and sloshing. The ship exhibited structural faults such as cracks that are considered common or somewhat routine on other bulk carriers of a similar age. If these are not identified and addressed in good time, more serious faults can arise. Ongoing and regular inspection is essential if such ships are to be operated to the required standard. The onus lies with the ship management company to ensure this issue is addressed through its ISM systems and that any applicable issues are brought to the attention of the Classification Society.

Stability

2.5.31 Minimum stability criteria are established to provide a safety factor against a ship capsizing on passage. Like most cape-size bulk carriers, the *Taharoa Express* had large stability reserves when fully loaded. As the stability analysis shows, however, the presence of free water on top of the cargo and consequential shift of cargo on the incident voyage significantly eroded those stability reserves, albeit the ship still met most of the stability criteria in that damaged condition.

2.5.32 The combined effect of free surface and the cargo shift was to reduce the GM by 71%. When listed at 22° the maximum GM still occurred before the minimum stipulated 25°. However, had the list been allowed to develop further to 32°, the *Taharoa Express* would have had no stability reserves and would have been prone to capsize, which would have been earlier than when down-flooding occurred. This shows how serious the effect of free surface and cargo shift can be, even for a cape-size bulk carrier

2.5.33 The crew had no way of controlling the amount of water in the holds or making changes to the ballast carried on board. Anything that prevented the ship reaching the safe haven of Tasman Bay, such as propulsion or power plant failure, would have put the ship and crew at significantly higher risk.

2.5.34 The stability program on board the *Taharoa Express* was not capable of adequately calculating the stability when the ship departed Taharoa, because the software was not able to determine the free surface correction to the GZ curve for the combination of iron sand and free water. No calculations were made by those on board to calculate the correct GM. Regardless of how inherently stable cape-size bulk carriers can be, it is a safety concern that the stability program on board was not able to assess the stability during normal loading conditions. The crew therefore had no way of quickly determining the stability condition of the ship as it left the terminal or after the cargo had shifted.

2.6 Ship design

2.6.1 When the *Taharoa Express* was converted to load slurry cargo, Class NK made an assumption that the ship did not have free water on board above the cargo when it put to sea. This was stated in the NKK loading manual for the safety of the ship with respect to stability.

2.6.2 Simplified sloshing calculations for the ship loading at the buoy based on best practice at the time were completed prior to the ship's conversion to load slurry. No calculations were carried out for the sea condition as it was assumed this scenario would not arise.

2.6.3 The NKK loading manual made reference to emergency de-canting owing to deterioration in the weather or a problem at the terminal, but not an on-board system failure. The latter was dismissed on the basis that shore technical assistance would be available when the ship was in port. This incident highlights that on-board system failure was possible and that shore assistance can be of little value if a ship is forced to depart owing to the weather.

2.6.4 Figure 7 shows the relationship over time between the level of iron sand and free water in the holds. The graph demonstrates that an interruption in the loading sequence can leave a considerable volume of water in the hold above the iron sand that can be only removed by de-watering, having not yet reached the level of the free water valves. The amount of water remaining would depend on what time the interruption occurred and the position of the de-canting valves in relation to the water level. In the normal course of events, had the ship been loading in a sheltered port this would not have been a critical issue, but it was critical because the ship was in an open port where it was vulnerable to the weather and the limitations of the single buoy mooring.

2.6.5 The point had already been recognised when the amount of sand carried in numbers 1 and 9 holds had to be reduced because of the new SOLAS requirement. Additional free-water valves were installed lower down, otherwise a significant time would have been needed to remove the free water using the slower de-watering system. Despite agreeing to look at ways of improving the efficiency of the de-canting and de-watering process in the risk assessment, extra valves had not been fitted in the other cargo holds, where a similar situation could have existed in the event of a premature stoppage in the loading process. What this meant was that during every loading the ship was in a vulnerable condition until the level of sand reached at least the lowest emergency free-water valve.

2.6.6 Before this incident, the assumption had been that loading would reach the end of the first or second stage. Because the ship could have been expected to leave the single buoy mooring or the port limits at short notice, it was important that each stage of loading start only when a suitable weather window existed to allow its completion with adequate de-watering time; otherwise the ship could be left with a substantial amount of free water above the cargo. Subsequent to this incident and as a result of post-incident investigations, the ship operator and port operator introduced such a system based on opportune weather windows, which should address this safety issue.

2.6.7 There was no back-up system on board the ship or at the port to remove free water in the event of a failure of the shipboard systems. The hold overflow system had 2 mains and 2 pumps, but all holds except number 5 relied upon a single valve to de-water. This valve was in the lower stool and access to operate it in an emergency was through the duct keel. This represented a single point failure in the system for which no contingency plan existed. Even in number 5 hold where 2 valves were fitted for de-canting, a flooded duct keel would have rendered both valves in the lower stool inaccessible.

2.7 The port risk assessment

2.7.1 Port reform in New Zealand led to a shift of responsibilities to the regional councils, some of which had little experience in maritime operations. Taharoa port was different in that the maritime regulator had supplied the harbourmaster before and after the reforms.

2.7.2 The evidence shows that there was little regulatory intervention with operations at the port, which at one stage operated unlicensed for 4 years. The harbourmaster function was essentially monitored by the deputy harbourmaster, who was also the pilot and loadmaster. The primary harbourmaster had little to do with the port and rarely visited. One harbourmaster of several years was not even aware that he had been appointed. No harbour bylaws existed until 2006. It was not until the series of incidents with the *Taharoa Express*, which corresponded with the timing of the development of the port safety code, that Port Taharoa came under scrutiny.

2.7.3 Prior to about 2002 NZ Steel Mining did not consider itself a port operator but a mining company only, a view that had never been challenged. The assets within the port were owned and utilised exclusively by NZ Steel Mining for exporting iron sand as they had been before port reform; nothing had changed. NZ Steel Mining felt it had no control over and no responsibilities for the safety of the export ships owing to the charter arrangements. As it was a mining and export company, this was probably true. The original charter arrangement was "free-on-board", which meant the purchaser supplied the ship, presented it to the port and NZ Steel Mining loaded it. As a port operator, however, NZ Steel Mining did have obligations and responsibilities for the safe operation of the port, as did the harbourmaster have responsibilities under the Local Government Act for ensuring the port operator was discharging those responsibilities. Those obligations existed even before they were later formalised in the port safety code.

2.7.4 The procedures that existed for the port were a simple reflection of how the port would receive ships and load the iron sand, and the ships depart. Any identified risks were largely of a commercial nature rather than risks to people and the environment. For many years the port had operated this way with few reported problems.

2.7.5 By way of example of the above, in 1984 the messenger line for the main hawser broke during a mooring operation, resulting in several fatalities on an export ship. It was not until 20 years later that the risk was recorded in the NZ Steel Mining risk register during a review, when "over tensioning of a messenger line" was first recorded and scored 8, or extreme.

2.7.6 An example of the confused nature of the application and lack of assessment of the risk controls is the fitting of a strain gauge to the ship to measure the hawser loads when the ship is at the buoy. The strain gauge was cited as a major contributor to safety at the buoy and data from the gauge was to be used to assess the effective life of the hawser and loads on the buoy as a whole. Maritime NZ said that it had tried to engage with NZ Steel Mining on a review of the load data and its implications for the operating parameters, but had not received a review; only the raw data, 2 years after it had been fitted. Similarly no information was passed on to the ship regarding the maximum loads that could be safely tolerated while the ship was moored at the buoy so that operational limits could be observed by those on board.

2.7.7 Through its harbourmaster function, Maritime NZ was responsible for conducting a harbour risk assessment for Taharoa. NZ Steel Mining as the port company was required to conduct a port risk assessment and be instrumental in the development of the risk controls and their inclusion in a safety management system. The harbour was the area defined by the limits set by the regional council; the port was a coastal marine area within a harbour occupied by a port company. In the case of Taharoa, the port and the harbour were in fact exactly the same area, because they had the sole purpose of iron sand export. In the context of the port safety code, only a single risk assessment was necessary.

2.7.8 The timing of the series of incidents involving the *Taharoa Express* and NZ Steel Mining's developing realisation of its responsibilities as a port operator under the port safety code prompted Maritime NZ to conduct its own risk assessment for the port and use it as a lead example for other port authorities to follow. The plan though, relied on the co-operation of NZ Steel Mining, which ultimately funded the cost of proposed risk controls resulting from the risk assessment.

2.7.9 The development of the risk assessment and safety management system started in late 2003. It was envisaged by Maritime NZ that the whole process would be completed in a few months. At the time of the incident, more than 3 years after the initial risk assessment conducted by Maritime NZ, the safety management system for the port of Taharoa had not been completed.

2.7.10 The initial proposed risk assessment process outlined by Maritime NZ and endorsed by harbourmaster reflected the proposed risk assessment guidelines under the proposed port safety code. Had the risk assessment methodology been followed, the principles of reducing the identified risks to as low as reasonably practicable should have provided a fair balance of safety versus cost, but instead the process was altered and the risk assessment that resulted was incomplete.

2.7.11 Under the port safety code the harbourmaster is recognised within the council as being responsible for ensuring a harbour safety management system is in place and functioning correctly. The harbourmaster was therefore the logical person to drive such a project in consultation with other stakeholders.

2.7.12 There was a difficult relationship between NZ Steel Mining and Maritime NZ, which meant that the actual process that was followed was somewhat different from that envisaged by the harbourmaster and others within Maritime NZ, who raised their concerns at the time.

2.7.13 An example of this difficult relationship followed after the mooring hawser failure in September 2003, When NZ Steel Mining had an independent review completed by the single buoy mooring manufacturer to determine if the loads on the buoy were within design criteria. This report was received by NZ Steel Mining in February 2004 and concluded that the mooring was being used outside its design criteria. NZ Steel Mining lowered the allowable wave height for the ship to remain on the buoy but not as low as that recommended in the report. Following numerous requests, Maritime NZ did not receive a copy of the report until June 2004; subsequently the allowable wave height was lowered further.

2.7.14 The single buoy mooring continued to be a contentious issue between NZ Steel Mining and Maritime NZ. The buoy had not been removed from the water since 1981, yet the manufacturer advised that normal practice was to remove single buoy moorings for inspection every 7 to 8 years.

2.7.15 In May 2006 the regional council reissued a resource consent certificate to NZ Steel Mining to operate, maintain and replace the existing mooring. The certificate was issued on condition that NZ Steel Mining, within one year of the certificate being granted, provided certification that the mooring buoy had been inspected and was sound and in a suitable condition for mooring vessels. Under the resource consent process Maritime NZ was advised after the consent was issued of the condition regarding the buoy. Some 2 years later and after previous failed attempts an agreement was reached between NZ Steel Mining and Maritime NZ that the buoy would be inspected and certified by a Classification Society and removed from the water in 2009. Failure of the single buoy mooring had always featured as a high-consequence event and a high risk in the risk assessment.

2.7.16 Maritime NZ's risk assessment was not complete. It essentially consisted of the same draft list of hazards provided to it to start the process, a list provided without the writer having visited the site or having the benefit of engaging with stakeholders.

2.7.17 The NZ Steel Mining risk assessment, although containing some operational safety risks, was largely focused on commercial risk.

2.7.18 The risk assessments used different scoring methodologies, so simply to combine them in a bow-tie matrix and apply the risk controls for one to the other could not work. A confused picture resulted.

2.7.19 Under the NZ Steel Mining methodology were a number of risks that in theory could not be reduced to ALARP owing to historical data. An example was the risk of having to depart the mooring buoy owing to bad weather having a low consequence but a high frequency, meaning it retained a high score. The hazard was not really even a hazard; it was a cause that created the risk of loss of revenue, for example. In reality there was a higher consequence for the safety of the ship.

2.7.20 Any risk assessment will only be as good as the scoring is accurate. If either the frequency or consequence is understated, the risk level will be also. For example, in the NZ Steel Mining risk assessment the frequency assigned to the hazard "ship colliding with mooring buoy" was once in 100 to 1000 years, yet records showed that it had occurred twice in a 2-year period.

2.7.21 In the Maritime NZ risk assessment, hazard number 10, "export vessel loss of stability margin on loading" identified a risk of a cargo shift, sloshing and structural failure. It was ranked the lowest of the hazards identified. The worst credible outcome was scored as zero consequence for people and the environment, presumably because the ship was no longer in the port and was not considered to be the port's problem. Under hazards 1 and 3, if the ship ran aground in the port, the consequence for people was scored as 7, presumably because the ship was still in the port and considered still under the harbourmaster's jurisdiction. This was possibly another example of ignoring problems facing other people in another part of the system mentioned earlier.

2.7.22 The Marico Marine report summarising the initial Maritime NZ hazard meeting delivered in December 2004, for hazard 10, "export vessel loss of stability margin on loading" identified the worst credible consequence as sloshing and cargo shift leading to internal structural failure and loss of the ship. There is no evidence that the potential for a shift of the iron sand cargo or the ability of the ship's structure to withstand internal sloshing was further explored. The harbourmaster raised concerns over sloshing in the ship's holds while loading and recommended that these forces be calculated. These concerns were highlighted subsequently in a printed report that was tabled by Maritime NZ to NZ Steel Mining for discussion on 22 March 2005. Examination of design criteria and loading instructions from the Classification Society would have shown that the ship had not been designed to put to sea with free water above the cargo.

2.7.23 Marico Marine, which facilitated the Maritime NZ risk assessment, stated that it had raised concerns at the hazard meeting about the fact that the ship was built during the optimisation period and the possibility of rapid structural damage from sloshing, a concern raised by the incumbent harbourmaster. This hazard could arise if the ship had to leave the single buoy mooring at short notice or inadequate de-watering had taken place. These were recorded in the hazard register.

2.7.24 The Marico Marine report summarising the initial Maritime NZ hazard meeting delivered in December 2004, for hazard 10, listed 3 risk control options to hazard 10 that had been identified at the meeting:

- extend harbour limit
- safety management system (Terminal)
- safety management system (Export vessel).

2.7.25 The second and third bullet points are an indication of the type of thinking described earlier. What these 2 statements are in effect conveying was that it was someone else's problem.

2.7.26 With respect to the first option Marico Marine further had raised the issue of a salvage buoy being provided to offer a safe haven within an extended harbour limit. This was intended to allow the ship to remain in the harbour limit and under the jurisdiction of the harbour authority. There is no evidence of a salvage buoy being tabled or recorded in the subsequent risk assessment process, but the recommendation of the harbour limit being extended was taken forward and eventuated.

2.7.27 The first option shows that the risks to vessel and crew were not given a priority, but instead the focus was on ensuring the ship did not venture outside the port limits and breach the various national and international rules around loading draughts and freeboard. Maritime NZ's position post incident on the reasoning for extending the harbour limit was an acknowledgement that the port did not offer a safe haven and was effectively a roadstead. It was done to provide a greater port area in which to anchor further from the shore in normal weather conditions.

2.7.28 The fact remains that owing to the exposed nature of the port, the ship was always prone to the elements from the time it moored and began loading free water into the holds. Generally any inclement weather requiring the ship to leave the buoy was from the west, placing the ship on a lee shore. The depth of water far enough off the beach was on the limits of that in which the ship could effectively anchor. There was no guidance on or assessment of the environmental conditions in which the ship could safely anchor or options if it had to put to sea. It also assumed that the ship's de-canting and de-watering systems were operational. The extension of the harbour limit alone did not reflect the conditions of assignment of the ship, that it was not designed to put to sea with free water above the cargo, whether anchored or not.

2.7.29 The bow-tie matrix in the Port Taharoa draft safety management manual at the time of the incident shows that there were no response measures identified for hazard 10 (see Appendix 5). This indicated that neither of the risk assessments considered that the risk was likely to eventuate, or if it did that it was a significant hazard.

2.7.30 It would be unreasonable to expect a port risk assessment to identify directly that unsealed cope holes in the lower stool of a ship can lead to a shift of cargo and put the ship and crew at extreme risk. An effective failure mode effect analysis of the ship when it was converted could have identified the bilge and ballast system as a critical component. The method of loading provided at the port created a known risk to the load vessel; this should have been identified by the port risk assessment.

2.7.31 This highlights an important point about any safety management system that it should consider interoperability with other safety management systems.

2.8 The draft safety management system

2.8.1 Correct hazard identification and risk assessment should, according to the port safety code, be one of the foundations for producing a port safety management system, and as such that process should be robust.

2.8.2 The original development of the safety management system was given to an outside contractor who had no involvement in the risk assessment and had not visited the port. This was a paper exercise and they were directed to not involve themselves in the practicalities of the risk assessment and were not invited to comment on it. The remit given was consistent with the fragmented way in which the risk assessment had been conducted. In the event, the contractor did not complete the project and the work was taken back in-house by Maritime NZ.

2.8.3 Since the incident the safety management system for the port has been developed and in January 2008 an independent peer review of the safety management system was undertaken at the port. The remit for the review did not specify a review of the risk assessment; however, despite this the review picked up on discrepancies in the process followed in undertaking the risk assessment. The review recommended that a single hazard register be maintained.

2.8.4 The review sanctioned the adoption of the safety management system and gave a number of recommendations. These included recommendations on maintenance practices for the single buoy mooring.

2.8.5 Safety management systems have been a requirement on board ships for many years, yet the ships interact with port companies that might not have safety systems designed around the same philosophy, or in some cases have very little in the way of safety systems at all.

2.8.6 Commentators on the British Port Marine Safety Code opined that raising the formal safety requirements regarding marine operations in ports to the level practised in other industries in the UK, and the fact that ports can demonstrate mitigation of risks, will inevitably put pressure on ships visiting British ports to tighten their implementation of the ISM Code. Therefore the Port Marine Safety Code may be the [vehicle] for raising safety levels in the marine industry.[23]

2.8.7 To a certain extent this has already been demonstrated with the *Taharoa Express*. As described in the safety actions section of this report, a number of improvements have been made to both the on-board and shore-based processes, partly in response to previous incidents and the incident under investigation and partly as a result of developing the risk assessment and the port safety management system.

2.9 The ship's ISM system

2.9.1 Accident reports and commentary from experts in nautical publications worldwide have reported variously about the effectiveness of the ISM Code for ships in improving maritime safety. There have been good reports citing companies that have fully embraced the concept of ISM for what it is, and other reports of shipping companies and the ships they operate doing enough to gain ISM Code certification, but not embracing the concept. Such operations are characterised by generic manuals placed on board to satisfy the auditor but that do not reflect what is actually done in practice.

2.9.2 The safety management system on board the *Taharoa Express* showed some characteristics of being a generic system used across a number of similar-type ships managed by the same company. Hachiuma Steamship Company Limited operated mainly bulk carriers and this was reflected in the standard procedures listed on how to deal with generic emergencies, but there was little that dealt with the special nature of the ship and the risks associated with it.

---

[23] "Design for Safety of Marine and Offshore Systems", by Prof In Wang and Dr Vladimir Trbojevic.

2.9.3 There is some question whether even in principle the ISM system should have passed a thorough audit. Examples of indicators that supported that view were:

- poor document control; several versions of key manuals were in use. The manual giving specific instructions for loading at Taharoa was not in the English, the working language of the ship
- no reference to some key documents; the bulk cargo and bulk loading codes, for example, were not mentioned, nor were they carried on board
- the hazards associated with the special nature of the cargo and the way it was loaded had not been identified
- the ship was not in compliance with the SOLAS requirement regarding carriage of bulk cargoes above its TML, nor did it have an exemption from that requirement
- critical components and systems were not identified
- the stability computer was not capable of accounting for the free surface effect of free water in the holds during the loading process
- crew resource management and communication in general between departments were not of a reasonable standard.

2.9.4 The loading operations manual did not identify the ship's de-canting and de-watering plant and ballast systems as being critical systems and did not outline any procedures to be followed in the event of a malfunction of either system, this in spite of reference to past incidents where the ship had sailed with free water on top of the cargo.

2.9.5 No reference was made to the bulk code and SOLAS regulations for the carriage of bulk cargoes. The ship did not carry sufficient documentation on the properties of the cargo it was carrying as required under SOLAS. The ISM Code stated that the safety management system should ensure compliance with mandatory rules and regulations, and that applicable codes, guidelines and standards recommended by IMO, Administrations, Classification Societies and marine industry organisations were taken into account.

2.9.6 It could be argued that these were issues with the design and documentation of the system and that the actual practice was more robust, but the failures that occurred in almost every part of the system during this incident suggest otherwise. In sequential order they are:

- the process, communications and quality control of repairs in the dry dock
- the communication and process on board for dealing with the alarm status of the duct keel
- the communication at all levels that allowed loading to continue for several hours once the duct keel flooding had disabled the critical ballast de-canting and de-watering systems
- no appreciation at all levels for the danger to the ship and crew posed by the free water on board on departure from Taharoa
- the standard of watch-keeping and crew resource management during the voyage to Tasman Bay
- the dubious standard of repair and communication with authorities over structural damage found on subsequent voyages.

2.10 Regulation regarding bulk carriers and the loading of bulk carriers

2.10.1 The load method at Taharoa was different from that for loading a conventional bulk carrier. The bulk code does not make separate provision for slurry loading, however it does represent international law and best practice for the carriage of bulk cargo. The fundamental risks that the code highlighted from a cargo shift were still applicable to the *Taharoa Express*.

2.10.2 The ship could not comply with SOLAS regulations with respect to TMLs, because the ship was designed to load iron sand as slurry. It was not until some time later in a voyage that requirements were met; this following the removal of free water on top and reducing the moisture content using the de-watering process.

2.10.3 The bulk code that supports the SOLAS regulation clearly outlined the risk of a cargo shift for cargo that may liquefy if the moisture content of the cargo were above its TML. Tests on the iron sand after the incident quoted a TML of 9.27%, indicating the sand was potentially liable to shift at or above that moisture content. Under the bulk code this information should have been supplied by the shipper and also requested by the ship's master before loading the cargo.

2.10.4 The bulk code recommended that the TML of solid bulk cargoes that could liquefy and were of consistent composition be tested at least once every 6 months. Testing of the TML of the export iron sand was not carried out frequently enough at Taharoa to comply with the bulk code recommendations.

2.10.5 The loading plan allowed for a period of de-canting at the end of loading, which was primarily to allow the removal of supernatant water above the cargo and to ensure that when the ship sailed the draught was reduced sufficiently before the ship left the port limits to comply with the International Load Line Convention.

2.10.6 Despite the differences in its loading process from that of a conventional bulk carrier, the *Taharoa Express*, once the cargo had been loaded, was potentially as much at risk as any conventional bulk carrier to a cargo shift while the cargo moisture content was above the TML. Prior to this incident the only indication that sailing with cargo above the TML was not a hazard to the ship, was that a cargo shift had not been experienced during the history of the operation. Unlike a conventional bulk carrier, however, water could be removed after sailing and the moisture content of the cargo reduced below the TML using the de-watering system.

2.10.7 With reference to the post-incident testing done on the characteristics of the Taharoa iron sand (see section 1.13), NZ Steel Mining in its submission to the Commission stated that it believed that sufficient data and analysis had been submitted to confirm that the Taharoa iron sand cargo was inherently stable under normal and existing slurry loading and sailing conditions and was not a cargo that may liquefy within the meaning given to the term in SOLAS and section 7 of the bulk code.

2.10.8 All the work done since the incident on understanding the characteristics of the iron sand should have been done many years ago. The information could have been presented as a safety case to the Flag State, together with information on how identified risks were mitigated, so that an exemption could have been issued. The exemption could have been issued on the proviso that certain conditions were met. That way everyone involved with the Taharoa operation, from the harbourmaster through to crew on board, would have been fully aware of the risks involved in the ship departing Taharoa on 22 June 2007.

2.10.9 The investigation into this incident does, however, raise some issues around the bulk code and the interpretation of it. None of these issues has affected the outcome of this incident because the code was not consulted by any party involved, but they are worthy of mention in the interest of continuous improvements in bulk carrier safety.

2.10.10 The bulk code lists the cargoes that are capable of liquefying, and although the list is not exhaustive there remains the possibility that cargo may be assumed to be safe when it is not, because it is not specifically listed. The Commission makes this point because it was put to it during the post-incident correspondence with key stakeholders that iron sand with the characteristics of that from Taharoa was not included in the list.

2.10.11 The bulk code section 7.2.3.1 contradicts section 7.2.4. An expert in cargo liquefaction disagreed with the statement made in section 7.2.3.1 that "when cargo contains very small particles, the movement of the particles is restricted by cohesion and water pressure does not rise". He believed that if the cargo is wet, the pore pressure will rise more rapidly among fine particles than coarser ones because the water cannot run off as quickly. He believed that the statement is dangerously misleading because it implies that cargoes of fine particles will not liquefy.

2.10.12 The expert believed that section 7.2.4 is more accurate but "(understandably) rather vague about a certain proportion of small particles and a certain amount of moisture; how small is small and how much moisture? I don't think we are in a position to offer a simple answer to that".

2.10.13 What this demonstrates is that, like all standards, guidelines and such like, these documents are part of an evolving process of learning. They are generally minimum standards based on knowledge available at the time. This is acknowledged in the ISM Code, which states that any safety management system should work on a philosophy of continuous improvement, particularly in learning from accidents and incidents and applying the lessons learned to improve the safety and efficiency of operations.

2.11 Summary

2.11.1 There is little doubt that when the *Taharoa Express* departed Taharoa into inclement weather, partly loaded with a significant amount of free water in the holds and with an unserviceable bilge, ballast de-canting and de-watering system, the ship was at significant risk. The evidence suggests that those involved in the operation were impervious to the risk of a cargo shift and structural failure of the *Taharoa Express*.

2.11.2 Whatever the mechanism for the cargo shift, by surface erosion or sliding or a combination of both, the ship's list was increasing. The rate at which the list was increasing was slowed by the recommended actions of the harbour pilot rather than the crew. Had action not been taken at that time, it is highly likely the ship would eventually have listed to a point of capsize. It is a matter of speculation as to when the crew would have taken action to intervene if the harbour pilot had not been on board, but the culture on board displayed throughout the incident sequence from the dry dock to Tasman Bay was one of deferring responsibility upward to the next most senior person, who might not necessarily be in the best position to make a decision.

2.11.3 The loading operation at Taharoa had been without significant incident for many years. An obvious question is why at the time of the incident and not before did these problems start to arise? The loading process at Taharoa had been essentially unchanged for 30 years. Earlier vessels modified for the Taharoa trade had been smaller, and some say better suited to the loading method.

2.11.4 The safe loading of a ship is reliant on the processes for the ship, the loading facility and the environs being compatible. Weaknesses or risks in one part of the process might be mitigated by strengths in another. Changing the process so that strengths or defences in one part of the system are removed can expose weaknesses in the other, and if nothing else the path for an accident or incident is set.

2.11.5 A rise in the number of accidents and incidents, or at least those that were reported or noticed, occurred around the time the *Taharoa Express* was introduced to the trade. There could be a number of reasons for that. The ship was larger than previous ships and was built in what is referred to as the "optimisation period" where the wholesale removal of steel from a ship's structure to optimise both building costs and cargo-carrying capacity reduced the global strength and made it more flexible. Equally though, the answer could lie in any difference between now and then in how safety was achieved on board. Chartering arrangements changed, and with that came a change in responsibilities for the management of the carrying ship. Economic times change and pressure inevitably comes to bear on maintenance of ships and shore facilities. Deferred maintenance eventually will result in a greater risk of component failure.

2.11.6 All of these factors that could increase the risk of an operation are supposed to be managed by the risk assessment process that lays the foundation for safety management systems. As alluded to earlier in this report, neither the safety management system for the ship nor the safety management system for the port had been fully developed or adhered to. The operation had not changed significantly since its inception and its robustness had not been seriously challenged by those in or regulating the operation.

3 Findings

3.1 The Taharoa Express suffered a flooded duct keel while loading iron sand as slurry because supernatant water from the slurry that was being de-canted into the overflow recesses in numbers 1 and 3 holds entered the duct keel through cope holes left unsealed following repairs during a recent survey in dry dock.

3.2 Water in the flooded duct keel entered the receptacles containing electro-hydraulic solenoids that operated valves in the bilge, ballast and cargo de-watering systems, disabling all 3 systems, which were critical to the loading operation underway at the time.

3.3 Uncertainty over responsibilities and poorly established protocols for line communication both on board the ship and between the ship- and shore-based management resulted in an additional 5000 tonnes of free water being loaded into the holds after control of the de-canting, de-watering and ballast systems was lost.

3.4 The Taharoa Express was forced to leave the mooring and clear the port owing to adverse weather, with about 17 800 m3 of free water on top of the cargo and 11 500 m3 in a slack ballast hold, which severely eroded the ship's stability reserves and made the ship vulnerable to capsize when the iron sand cargo began progressively to shift.

3.5 Local damage occurred to the ship's structure when its design parameters were exceeded by the sloshing forces created by free water on top of the cargo and in the partially filled number 6 ballast/cargo hold. Although not conclusive, it was highly likely that symmetrical buckling of the aft corrugated bulkhead in number 1 hold was caused by dynamic forces of the cargo weight, possibly exacerbated by sloshing of supernatant water in the hold.

3.6 The prime mechanism for the cargo shift was most likely water sloshing in the hold causing the entrainment of sand by wave action on the cargo surface, the sand gravitating to the low side of the hold caused by the initial and worsening list. An en masse shift of saturated sand in one or more holds could not be ruled out, and became increasingly possible as the list increased.

3.7 When the Taharoa Express sailed from Port Taharoa on 21 June 2007, nobody on the ship, in the ship management company, in the port loading operation and in the various regulatory authorities had sufficient knowledge of the properties of the iron sand on board; nor did they recognise the peril the ship and crew faced from potential structural failure owing to sloshing, and potential capsize owing to cargo shift and the free surface effect of water in the cargo holds of the ship.

3.8 The regulatory involvement and oversight of the Port Taharoa operation had been below standard for more than 30 years until the introduction of the port safety code corresponded with the timing of a series of incidents involving the *Taharoa Express*.

3.9 Every person or entity that had some responsibility for oversight of the ISM system on board the *Taharoa Express* did not ensure that safety-critical systems were identified and managed, did not ensure that repair and maintenance were being carried out to standard, did not ensure that compliance with New Zealand rules, flag requirements and international conventions was being achieved, and did not ensure that the required level of communication on board and between other stakeholders was being achieved. They were:

- the master and crew
- the ship operator
- the Flag State Panama through its Recognised Organisation Class NK
- Class NK with respect to its own Class rules.

3.10 At the time of the incident the risk assessment undertaken by Maritime NZ and NZ Steel Mining for Port Taharoa in preparation for building a safety management system for the port has not been completed in line with Maritime NZ guidelines and, in its draft form 3 years after having started, was significantly flawed.

3.11 The potential for the Taharoa Express or previous export vessels to capsize and/or sustain major structural failure owing to cargo shift and sloshing by free water in the holds was a foreseeable risk that should have been identified many years before this incident.

3.12 The Taharoa Express is exhibiting the signs of an ageing bulk carrier that was built in the "optimisation period". The type of local and structural failures occurring during both normal and abnormal operations suggests the ship should be entered into a more rigorous survey programme until retired from the Taharoa trade.

4 Safety Actions

Class NK and IACS

4.1 The Commission has forwarded this report to Class NK and asked for comments on the actions it has taken to rectify the serious failings of its systems identified in the report. The report has also been forwarded to IACS to bring to the attention of its member Classification Societies the safety issues identified in this report.

NZ Steel Mining

4.2 Since the incident the following new procedures have been adopted on board the ship:

- pre-load briefing document distributed to all parties
- shipboard instructions to stop loading immediately if problem found in ballast, de-cantingor de-watering systems
- loadmaster to be informed of the status of ballast, de-canting and de-watering systems before and during loading operations
- safe management of the loading with respect to the free water on board in the weather window available before the buoy parameters are likely to be exceeded
- responsibilities of shipping agent defined and emergency contact numbers updated
- new load procedure adopted whereby numbers 3 and 7 holds are loaded in one pass, reducing exposure to free water.

The *Taharoa Express*

4.3 Since the incident the following actions have been taken by the ship management company:

- a duct keel bilge alarm indication has been fitted in cargo control office
- duct keel aft bilge line capacity increased from 65 mm bore to 100 mm to increase pumping capacity
- additional free-water valves fitted in overflow recesses in all holds to reduce the amount of supernatant water on top of the cargo at the end of each stage of loading. This has reduced the de-watering time at the single buoy mooring because less supernatant water is removed by de-watering
- on-board procedures manual updated to include emergency response in event of duct keel alarm
- on-board procedures manual updated to include emergency response to a malfunction of ballast, de-canting or de-watering systems

- on-board procedures manual updated with respect to lines of communication in the event of a malfunction or emergency on board.

5 Safety Recommendations

Safety recommendations are listed in order of development, not in order of priority.

5.1 On 27 April 2009 the Commission recommended to the Director of Maritime New Zealand that she:

013/09 Address the safety issue whereby the risk assessment for the Port of Taharoa that was in its draft form, after 4 years of development, did not follow the recognised methodology to classify and apply the appropriate measures to mitigate the risks. The safety management system that the risk assessment underpins must be regarded as fragile until an expert independent total review of it is made.

014/09 Address with the port operator and the owner of the port safety management system the issue whereby the mandatory requirements of SOLAS and New Zealand Maritime Rules, including reference to guidelines such as the Code of Safe Practice for Solid Bulk Cargoes and the Code of Practice for the Safe Loading and Unloading of Bulk Cargoes, have not been incorporated into standard operating procedures, nor have they been followed.

015/09 Forward this report to Panama, the Flag State for the Taharoa Express, and invite its comment on how it will address the safety issue whereby an analysis of the sloshing forces the free water imparts on the structure of the Taharoa Express during loading in the open port was not fully considered by the Classification Society on behalf of Panama when the ship was converted for slurry loading. A formal safety assessment should be undertaken and a special survey programme introduced depending on the results.

016/09 Forward this report to Panama, the Flag State for the Taharoa Express, and invite its comment on how it will address the safety issues with the ship's international safety management system identified in this report, particularly in relation to compliance with statutory standards contained in SOLAS and New Zealand Maritime Rules, communications, identifying critical systems on board, inspection of the ship's structure and interoperability with port operations.

017/09 Forward this report to Panama, the Flag State for the Taharoa Express, and invite its comment on how it will address the safety issue where the stability computer on the ship was not capable of calculating the free surface effect of the free water in the cargo holds during the loading process, so that when the ship was forced to put to sea prematurely, the true stability of the ship could not be quickly and efficiently calculated.

018/09 Forward this report to Panama, the Flag State for the Taharoa Express, and work with it on how it is going to address the issue concerning the past and current loading procedure for the Taharoa Express, which results in the ship sailing with the iron sand cargo above its transportable moisture limit, without a formal assessment having been conducted to determine whether the cargo is capable of liquefaction under normal load and transit conditions, and without determining whether the Flag State Panama should grant an exemption for sailing with its cargo above transportable moisture limit.

019/09 Forward this report to the International Maritime Organization and invite the appropriate committee to note the contents of the report with a view to any future amendments to the Code of Safe Practice for Solid Bulk Cargoes and the Code of Practice for the Safe Loading and Unloading of Bulk Cargoes.

5.2 On 8 May 2009, the Director of Maritime New Zealand replied:

013/09 The Director accepts this recommendation and has commissioned an independent organisation to carry out a full risk assessment of Port Taharoa, preparatory to development of an updated safety management system. The risk assessment will use the methodology contained in the guidelines to the Port and Harbour Marine Safety Code and will, amongst many other matters, take account of the interface between the onshore pumping operation and the safety management system of the ship for cargo operations. It is anticipated that the safety management system will be complete by 30 August 2009.

014/09 The Director accepts this recommendation and will ensure that the port operator and the owner of the port safety management system has incorporated the mandatory requirements of SOLAS and maritime rules, including references to the Code of Safe Practices for Solid Bulk Cargoes and the Code of Practice for the Safe Loading and Unloading of Bulk Cargoes into standard operating procedures. The Director will also ensure that the ***Taharoa Express*** is fully compliant with these requirements before the next cargo is loaded in June 2009.

015/09 The Director accepts this recommendation and will forward a copy of the report to the Panamanian maritime administration, drawing their attention to this recommendation and requesting a written response within three months as to how this safety issue will be addressed.

016/09 The Director accepts this recommendation and will forward a copy of the report to the Panamanian maritime administration, drawing their attention to this recommendation and requesting a written response within three months as to how this safety issue will be addressed.

017/09 The Director accepts this recommendation and will forward a copy of the report to the Panamanian maritime administration, drawing their attention to this recommendation and requesting a written response within three months as to how this safety issue will be addressed.

018/09 The Director accepts this recommendation and will forward a copy of the report to the Panamanian maritime administration and will ensure that the ship is fully compliant with international standards for carriage of bulk cargoes at all times through Port State Control inspections and verification of operational standards and procedures for carriage of bulk cargoes.

019/09 The Director accepts this recommendation and will forward the report to the Secretary General of the International Maritime Organisation drawing his attention to this safety recommendation.

Approval on 23 April 2009 for publication

Hon W P Jeffries
Chief Commissioner

Appendix 1 Load sequence for the *Taharoa Express*

Loading Sequence (A) TAHAROA, NZ

		10.0 Hrs	15.0 Hrs	17.1 Hrs	26.5 Hrs	40.6 Hrs	45.3 Hrs	50.0 Hrs	54.0 Hrs	78.0 Hrs	Voy 65 Taharoa	Express
	ARR	1	2	3	4	5	6	7	8	9	DEP	
CH #1	Nil DMT				10,000 DMT		4,700 DMT	800 DMT		De-Water 24 Hrs	15,500 DMT	
CH #3	Nil DMT	12,000 DMT				16,000 DMT					28,000 DMT	
CH #5	Nil DMT		10,000 DMT	2,000 DMT				8,200 DMT	7,600 DMT		27,800 DMT	
CH #7	Nil DMT	12,000 DMT				16,000 DMT					28,000 DMT	
CH #9	Nil DMT			1,000 DMT	11,000 DMT		4,700 DMT				16,700 DMT	
Total	Nil DMT	24,000 DMT 42,489 WMT	34,000 DMT 57,288 WMT	37,000 DMT 69,278 WMT	58,000 DMT 92,284 WMT	90,000 DMT 118,457 WMT	99,400 DMT 12,7546 WMT	108,400 DMT 130,603 WMT	116,000 DMT 134,457 WMT		116,000 DMT 128,144 WMT	
F	8-00	10-07	10-34	9-12	10-91	14-30	15-48	16-16	16-65		16-00	
A	9-26	10-81	10-69	13-06	14-24	15-67	16-36	16-27	16-65		16-00	
M	8-63	10-44	10-52	11-09	12-58	14-99	15-92	16-22	16-65		16-00	
T	1-26/S	0-74/S	0-35/S	3-94/S	3-33/S	1-37/S	0-88/S	0-10/S	0-00		EVEN	
S.F	-86%	-95%	-94%	84%	88%	-92%	-90%	54%	79%		69%	Ocean Mode
B.M	-87%	-76%	-87%	41%	95%	-43%	76%	38%	-74%		-52%	
FP	3688	3688	3688	3688	20	20	20	20	20	20	20	
1 C DB TS	3231	3231	3231	3231	20	20	20	20	20	20	20	
2 DB P&S	5888	1200	1200	1200	40	40	40	40	40	40	40	*Signed*
2 TS P&S	2548	0	0	0	0	0	0	0	0	0	0	……….
3 DB P&S	5804	5804	40	40	40	40	40	40	40	40	40	Chief Off.
3 TS P&S	4130	4130	0	0	0	0	0	0	0	0	0	
4 DB P&S	5486	5486	5486	40	40	40	40	40	40	40	40	
4 TS P&S	4130	4130	0	0	0	0	0	0	0	0	0	
5 DB P&S	1912	1912	1912	40	40	40	40	40	40	40	40	
5 TS P&S	0	0	0	0	0	0	0	0	0	0	0	*Signed*
AP	0	0	0	0	0	0	0	0	0	0	0	……… Master
6CH	18665	1000	1000	1000	1000	0	0	0	0	0	0	
TTL	55462	30561	16537	9217	1200	200	200	200	200	200	200	

Abbreviations Appendix 1

A	draught aft ship
AP	aft peak
B.M	bending moment
C	centre
CH	cargo hold
DB	double-bottom tank
DMT	dry metric tonne(s)
F	draught fore ship
FP	forepeak
M	draught mid-ship
P&S	port and starboard
S.F	shear force
T	trim
TS	topside tank
TTL	total
WMT	wet metric tonne(s) includes iron sand and water

Appendix 2 Previous incidents involving the *Taharoa Express*

March 2003: Crack in intermediate propeller shaft

A crack was discovered in the intermediate propeller drive shaft during maintenance by the ship's crew when the *Taharoa Express* was loading at the single buoy mooring at Taharoa. The crack was ground out but more cracks appeared in the shaft after the ship departed Taharoa. Eventually the ship was towed back to Japan. Maritime NZ conducted its own investigation and published a report with its findings of the incident.

In its findings of the preliminary report, Maritime NZ noted that the crack in the shaft was probably from a defect when the shaft was originally cast.

One of the key conditions that the report noted was:

> Of the vessel's nine holds only five, No.'s 1, 3, 5, 7 and 9 were used for loading ironsands, leaving No.'s 2, 4, 6 and 8 empty. The approximate depth of each hold is about 24m. When fully loaded, the ullages at the loading holds (the cargo is loaded as a slurry, which is gradually dewatered on the passenger to Japan) is about 12metres. Effectively on departure when the vessel is fully loaded, the holds are still only half full. According to the harbour master/pilot at Taharoa, he has on occasion taken the vessel off the SPM [single buoy mooring](for example because of bad weather) when tonnages have varied from 50,000 through to 120,000. On none of these occasions was the safety of the vessel considered to be at risk for reasons such as free surface effect from the slurry cargo.

At the time the ship had de-watered on the single buoy mooring for approximately 7 hours before its departure. The report did not state whether there was still free water lying on top of the iron sand at the time of the incident or on the other occasions mentioned.

22 September 2003: Mooring rope failure at single buoy mooring

On 22 September 2003, a mooring rope failure while the *Taharoa Express* was loading at the single buoy mooring in Taharoa required the ship to leave the port before loading had been completed.

Both NZ Steel Mining and Maritime NZ conducted independent investigations into the failure of the mooring rope. In October 2003, Maritime NZ held a meeting with NZ Steel Mining; the purpose of that meeting was to prevent a future incident and take a wider view of the risks associated with operations at the port. The mooring rope was inspected by the local agent of the manufacturer. The Maritime NZ report recommended that another independent assessment of the rope be made and that a spare rope within its life cycle be used for the next load, until a new replacement had been delivered.

22 February 2004: Engine failure at single buoy mooring

In February 2004, the *Taharoa Express* suffered an engine start failure while it was mooring at the buoy at Taharoa. The ship was able to deploy its anchors and later leave the harbour under its own power to effect repairs. The ship safely moored at the buoy to load cargo 3 days later.

This incident was investigated by Maritime NZ and a report with recommendations published. One of a number of recommendations made by Maritime NZ was that a risk analysis should be undertaken of the ship mooring at the buoy when part loaded. Maritime NZ also identified to Hachiuma Steamship Company Limited, the ship management company, deficiencies in the ISM of the ship and recommended a drift study be completed of the ship in varying weather conditions. The ship management company after this incident started work on an "operation procedures manual at Port Taharoa" for the *Taharoa Express;* the first issue of this was subsequently published in April 2004.

Appendix 3 Bulk carrier casualty statistics

INTERNATIONAL MARITIME ORGANIZATION

IMO

E

MARITIME SAFETY COMMITTEE
84th session
Agenda item 23

MSC 84/INF.12
6 March 2008
ENGLISH ONLY

ANY OTHER BUSINESS

Bulk Carrier Casualty Report

Submitted by the International Association of Dry Cargo Shipowners (INTERCARGO)

SUMMARY	
Executive summary:	This paper provides information on the number of bulk carrier losses detailed in INTERCARGO's annual casualty report
Strategic direction:	5.2
High-level action:	5.2.1
Planned output:	
Action to be taken:	Paragraph 3
Related documents:	None

1 INTERCARGO recorded 8 bulk carrier losses in 2007 and 39 lives lost.

2 The trend in terms of long term losses of lives and ships remains on a downward trend, but further progress towards a goal of zero losses remains elusive.

Action requested of the Committee

3 The Committee is invited to note the information provided at annex.

***

ANNEX

BULK CARRIER CASUALTY REPORT 2007

SUMMARY

1 Eight bulk carriers or similar dry bulk vessels were lost during 2007 – an increase of one on the previous year. Again, this must be set against the ever expanding dry bulk fleet, estimated to have grown from 6,046 vessels on 31 December 2006, to 6,342 vessels on 31 December 2007. A total of 39 lives were lost on 2 vessels; compared to the same figure on a total of three vessels in the previous year. The average age of bulk carriers lost in 2007 was 25.5 years against a world wide trading average age of 14.85 years.

INTRODUCTION

2 Although a more comprehensive analysis will be available in due course, INTERCARGO has detected certain trends within the last one to two years, which call into question the ongoing sustainability of the long-term trend in improvements in recent years.

2.1 One of the common findings of these and subsequent casualties involved trading routes or management centres outside the three primary trading centres focused on the Paris MoU, Tokyo MoU and United States Coast Guard spheres of influence.

2.2 Although the number of vessels on voyages which commenced or were due to end in China is not in itself noteworthy, the loss of two smaller vessels engaged on the intra-Asian iron ore trades denotes a possible trend. In the case of the **Mezzanine**, the vessel had two port State control (PSC) detentions in China resulting in a deficiency per inspection rating placing the ship in the worst performance standard category. Similarly, the **Ever Winner** had been involved in trades outside the three main PSC areas and had not therefore been inspected since 2005. It is a matter of pure conjecture whether the fact that the transfer of the vessel to a new single-ship management company only one month prior to the accident may have played any part in the casualty, but some analysis of the chartering vetting techniques in this regional area would perhaps give an indication of root causes and possible preventative measures.

2.3 We look forward to seeing subsequent accident investigation reports which INTERCARGO believes should be placed in the public domain to ensure the maximum transparency possible. We hope that all subsequent accident reports will cover an analysis of the evacuation techniques used on the various vessels and whether any enquiry will be initiated by the flag State to cover, in particular, the effectiveness of conventional lifeboats when used on the **Mezzanine** accident and elsewhere. The part played by the various search and rescue services, together with the fortuitous proximity of passing ships is acknowledged as a major factor preventing further loss of life in 2007.

2.4 We cannot say with certainty that any particular casualty was caused as a result by structural issues although there are questions over the number of vessel losses attributed to "flooding". This aspect warrants further analysis in due course.

ANALYSIS OF TOTAL LOSSES

	In 2007	In 10-year period 1998-2007
Lives	39	318
Ship losses	8	86

Trends
(Figures are rounded)

	Lives Lost	Ships Lost
1990 – 1999	78	14.5
1991 – 2000	74	13.5
1992 – 2001	62	11.6
1993 – 2002	60	10.9
1994 – 2003	52	10.5
1995 – 2004	42	9.6
1996 – 2005	38	9.7
1997 – 2006	37	8.9
1998 – 2007	32	8.6

Size of vessels lost

	In 2007	In 10-year period 1998-2007
Handysize	5	52
Handymax	2	13
Panamax	0	12
Capesize	0	9

Age of casualty

	In 2007	In 10-year period 1998-2007
0 – 4 years	0	3
5 – 9 years	0	6
10 – 14 years	1	4
15 – 19 years	0	14
20 – 24 years	3	29
25 + years	4	30

Cause of incident

	In 2007	In 10-year period 1998-2007
Structural	0	12
Fire and Explosion	0	10
Machinery Failure	1	6
Flooding	4	13
Collision	1	15
Grounding	1	21
Contact object	0	1
Cargo loading/cargo shift	0	5
Other/Unknown	1	3

Appendix 4 IMO Circular DSC/ Circ.14 Compliance with the bulk code

INTERNATIONAL MARITIME ORGANIZATION
4 ALBERT EMBANKMENT
LONDON SE1 7SR

Telephone: 020 7735 7611
Fax: 020 7587 3210
Telex: 23588 IMOLDN G

IMO

E

Ref. T3/1.01

DSC/Circ.14
15 October 2003

COMPLIANCE WITH THE PROVISIONS OF THE CODE OF SAFE PRACTICE FOR SOLID BULK CARGOES (BC CODE)

1 The Sub-Committee on Dangerous Goods, Solid Cargoes and Containers (DSC), at its eighth session (22 to 26 September 2003), considered a submission relating to the outcome of an incident investigation report (DSC 8/4/2) on the transport of ammonium nitrate based fertilizer.

2 The Sub-Committee's attention was drawn, in particular, to reported incidents caused by the lack of adherence to the provisions of the BC Code by those in charge of ships and transport of solid bulk cargoes.

3 The Sub-Committee, in view of the above, wishes to:

- .1 draw the attention, once again, of shipowners, ship operators, companies and charterers involved in transport of solid bulk cargoes to:
  - .1 the need to provide the master with the relevant information on the cargo in accordance with chapters VI and VII of the SOLAS Convention and the provisions of the BC Code; and
  - .2 the need, when transporting any solid bulk cargo, to consult the BC Code;
- .2 recommend to shippers and shipmasters:
  - .1 to ensure, before the loading of any solid bulk cargo, the suitability of the hold and its equipment for the product to be transported; and
  - .2 to only commence loading if all of the relevant safety criteria contained in the BC Code are met;
- .3 recommend to shipowners, ship operators, and companies involved in the transport of solid bulk cargoes to train their crews in the provisions of the BC Code, including the safety measures contained therein, to integrate them into their ISM procedures and to carry any necessary safety equipment required by the Code.

4 Member Governments are invited to bring the above information to the attention of shipowners, ship operators, companies, shipmasters, shippers and all other parties concerned requesting that appropriate action be taken in accordance with the provisions of the relevant IMO instruments when transporting solid bulk cargoes.

———

I:\CIRC\DSC\14.doc

Appendix 5 Port safety code risk assessment guidelines

In the port safety code risk assessment guidelines, an explanation of stage 2, the hazard identification process, is outlined in section 3.1.2 and is quoted below:

> The process of hazard identification is likely to begin soon after stage 1 has commenced and a preliminary list should have become available almost as a direct output from this stage. Hazard identification is, in many ways, the most critical of the steps involved in the risk assessment process. An overlooked hazard is more likely to introduce error into the overall risk assessment of a port or harbour, than an accurate assessment of frequency or consequence. In many cases, errors made in assessing consequence and frequency can cancel each other out over the full spectrum of incidents, whereas the omission of a hazard results in an underestimation of the overall risk profile. Moreover, important risk control may not be introduced to properly manage the risk, resulting in an accident waiting to happen.
>
> The facilitator of a HAZID meeting is the key to a successful delivery of the hazard information and the role is often combined with that of the chairman. There are few areas where the risk assessment can truly benefit from a specialist, but this is one of them. An experienced HAZID chairman can make a real difference in the delivery of the information from participants. All ports and harbours intending to undertake their own risk assessments are strongly recommended to consider as a minimum, using a specialist to facilitate their HAZID. All stakeholders should participate in the HAZID at some stage in its agenda. It is vital to involve regular harbour users at this stage.
>
> The aim of the exercise is to identify all hazards; even those managed by existing risk control measures. Within this stage, one or more structured meetings (HAZID meetings) with those having experience of vessel movements and berthing in the location should be held. It is strongly advisable to have some form of independent attendance at the HAZID meeting, which could be expertise from a neighbouring council or port company. This approach recognises that the people best placed to identify hazards are often personnel working within the port or harbour, but that a "new pair of eyes" also notices items of significance that are accepted as normal in the system. The benefits provided by those outside pair of eyes are very important to the success of the risk assessment. It is perhaps obvious that risk assessments undertaken totally in house do not generally address all the issues, some of which will be related to problems that the organisation with the responsibility has hesitation in addressing.
>
> The HAZID process should be conducted on an Incident Category basis, across each area of the port or harbour. It should systematically consider vessel types, operations and interfaces appropriate to each area. The approach will be to undertake Hazard Identification on a geographical basis, followed by a number of smaller meetings concentrating on specific areas and assessment of specific operations.
>
> Hazards should be identified initially on a generic basis and then added in order to consider scenarios specific to different areas of the port or harbour.

Appendix 6 Risk assessment for Port Taharoa

Original scoring of hazards 9 and 10 by Maritime NZ after harbourmasters' hazard identification meeting in April 2004. Extract from Marico Marine draft risk assessment summary report.

Report No: 04JR382
Issue : 1

TAHAROA OFFSHORE TERMINAL

MARICO MARINE

Hazard ID No.	Ranked No:	Category	Area	Vessel Type	Hazard Title	Hazard Detail	Possible Causes	Most Likely	Worst credible	Assessed Risk: Most Likely: People	Property	Environment	Business	Assessed Risk: Worst Credible: People	Property	Environment	Stakeholders	Remarks	Risk No.
9	14	Personal Injury	SBM	Capesize BC	Pilot Boarding injury	Pilot injured whilst Boarding from helicopter or boat	HUMAN Swell/weather boarding criteria exceeded Helicopter landing parameters not followed Vessel heading: unsuitable motion MECHANICAL Helicopter landing area deficiency ENVIRONMENT Swell / weather	Heavy landing . Pilot trips and falls sustains minor injury, bruising	Helicopter lands at hatch cover edge, Pilot falls, possibly from hatch top.. Pilot injury. Berthing delay.	0	0	0	0	5	0	0	3	Pilots (and others) may lose footing during helicopter operations mainly due to transferring from one moving platform to another. The same is true for boarding by boat although the injury might also include falling into the water.	1.74
10	15	Loss of Hull Integrity	SBM	Capesize BC	Loss of Stability Reserve	Vessel suffers loss of stability margin on loading	HUMAN Inadequate Dewatering procedures. Overladen vessel on departure. Unplanned rapid disconnection - weather deterioration. MECHANICAL Unsuitable vessel for operation. ENVIRONMENT Unexpected adverse weather	Stability reserve of Capesize results in no consequence.	Sloshing and cargo shift. Listing and shell plating/internal structure failure.	0	0	0	0	0	4	0	4	Panamax and smaller size bulk carriers more susceptible to free liquid effects than Capesize BC.	1.66

New Zealand Maritime Safety Authority

Page B10

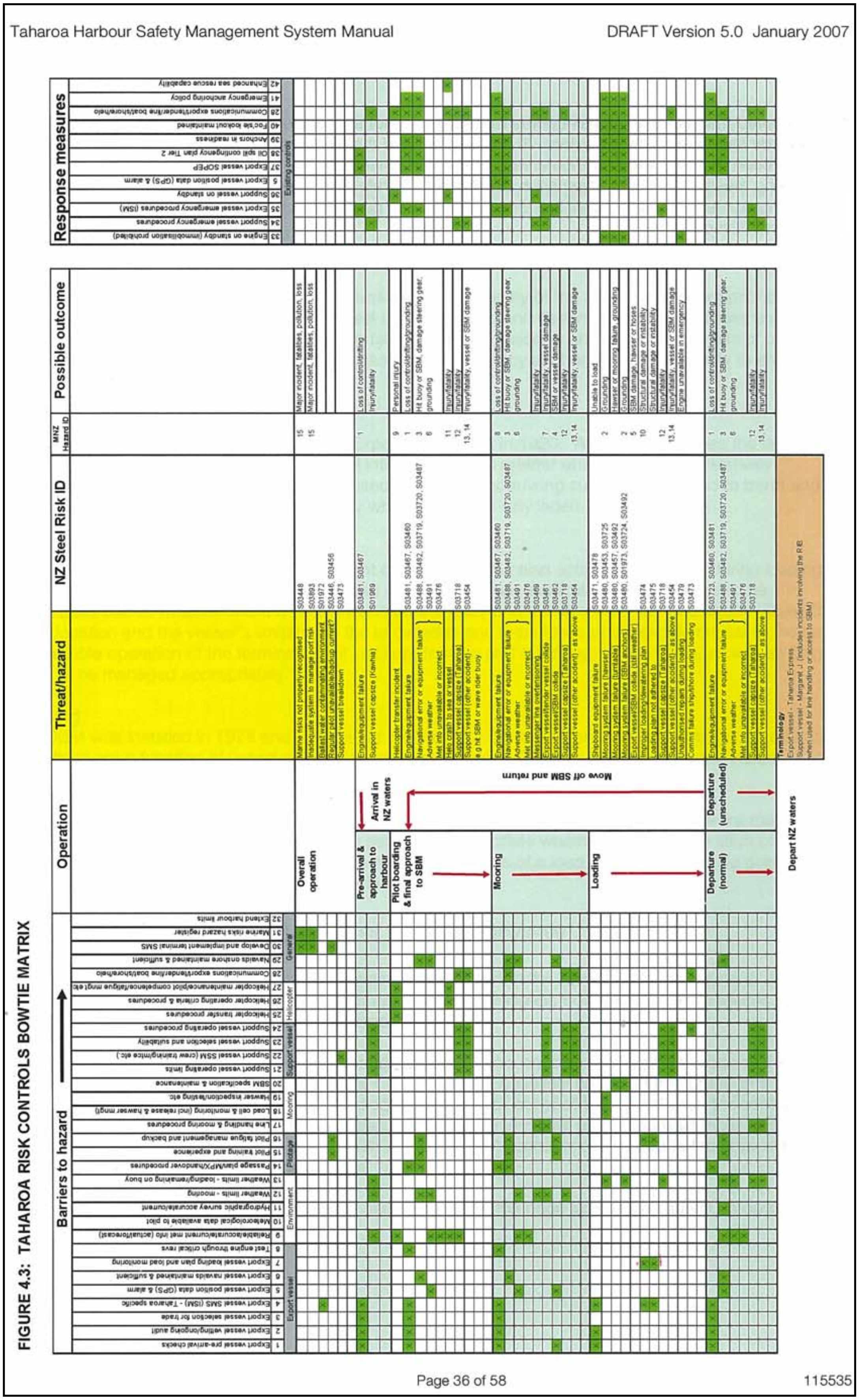
Summary of scoring of Maritime NZ hazards in Port Taharoa draft safety management system manual at time of incident in June 2007.

Taharoa Harbour Safety Management System – Appendices DRAFT Version 5.0 January 2007

Table 3.5: Maritime NZ Risk Summary Sorted by Hazard Ranking

Haz ID	Description	Risk Score	Hazard ranking	Risk - highest of (most likely, max. credible) People	Environ-ment	Property	Business
1	Export vessel loss of propulsion/steering through system or component failure	6.4	1	4	7	7	7
2	Failure of mooring line or SBM anchoring during connection or loading	6.0	2	7	6	7	7
3	Export vessel grounding in SBM approaches due to operational failures	5.8	3	4	6	7	7
8	Export vessel grounding during approach to SBM	5.4	4		7	7	6
11	Helicopter crash (into sea or onto deck of export vessel)	5.0	5	6	2	6	5
15	Implementation of SMS	4.0	6	2	3	4	7
12	Mooring boat capsize during operations	4.0	7	6	2	3	3
4	Export vessel contact with SBM during attachment	3.5	8			6	6
7	Export vessel collision with line handling craft during approach to SBM	3.2	9	4	2	3	2
13	Mooring boat contact with SBM	3.1	10	6	2	3	3
5	Export vessel contact with SBM (still weather)	2.8	11			4	4
6	Export vessel contact with wave rider buoy	2.3	12		2	3	3
14	Mooring vessel contact with wave rider buoy	2.1	13	3		3	3
9	Pilot injury during transfer to/from helicopter	1.7	14	5			3
10	Export vessel loss of stability margin on loading	1.7	15			4	4

Bow-tie matrix from Port Taharoa draft safety management manual.



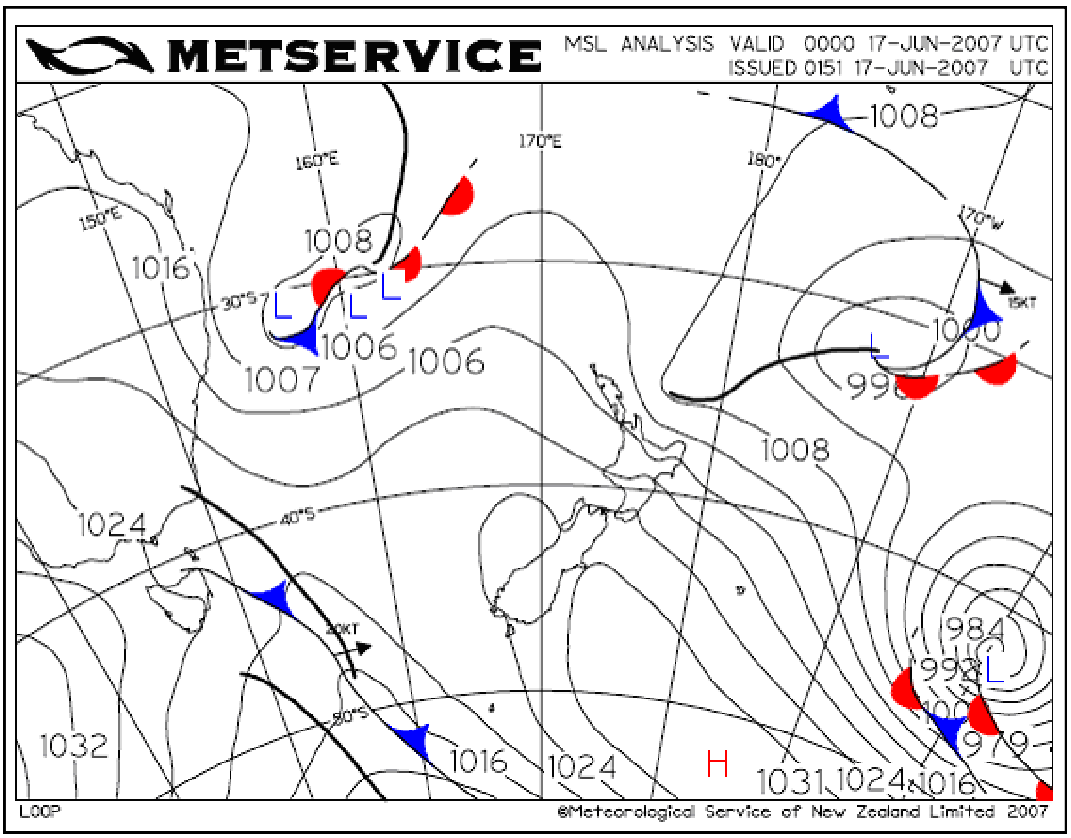
Appendix 7 Climatic conditions

The Meteorological Service of New Zealand Limited (MetService) coastal weather forecasts are a general indication of average conditions expected in a particular coastal area. The forecasts are for open waters within 60 nm of the coast and do not apply to enclosed areas such as small bays and harbours.

The port of Taharoa was located within the coastal forecast area of Raglan; the limits of the area were Muriwai to the north and cape Egmont in the south. The area of the coast between capes Egmont and Tasman Bay through which the ship sailed seeking a safe haven came under the coastal forecast area of Stephens.

On 17 June 2007 at 1243, the day before the *Taharoa Express* was due to arrive at Taharoa, MetService issued a marine weather bulletin for New Zealand coastal waters as follows:

> SITUATION AT 1200 NZST [New Zealand Standard Time] ON 17 JUNE 2007~
> A ridge over the South Island moves onto central New Zealand on Monday, easing the strong southeast flow over the North Island. A front should move over the South Island from the southwest during Tuesday, then over eastern parts of the North Island on early Wednesday followed by a narrow ridge. A low over the west Tasman Sea is expected to move southeast and deepen, crossing the North Island during Thursday.



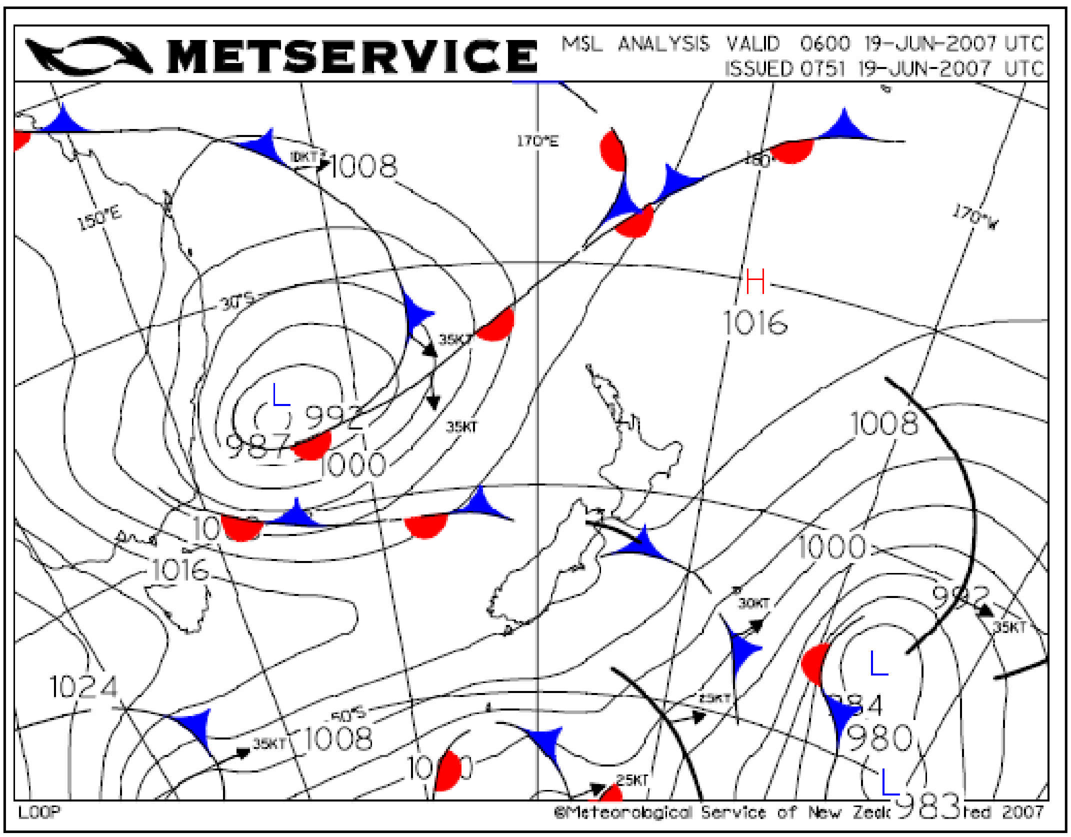
Mean sea level analysis for 17 June 2007 1200 NZST

On 17 June 2007 at 1230 NZST, the Metservice coastal forecast for the area of Raglan valid until midnight 18 June was as follows:

RAGLAN
Southeast 30 knots but 20 knots north of Kawhia, easing to 20 knots in the south this evening. Becoming southwest 15 knots everywhere Monday afternoon. Rough sea in the south easing. Southwest swell 2 metres.
OUTLOOK FOLLOWING 3 DAYS: Southwest 15 knots tending early Wednesday northeast 20 knots, rising late Wednesday to easterly 30 knots, becoming Thursday southwest 20 knots. Sea rough for a time. Moderate swell at times.

On 19 June 2007 cargo operations ceased at 1900. On 19 June at 1646, the MetService coastal forecast for the area of Raglan valid until midnight 20 June was as follows:

RAGLAN
GALE WARNING IN FORCE
Variable 10 knots becoming northeast 20 knots early morning and rising to 35 knots late morning, then easing to northerly 20 knots Wednesday afternoon. Sea becoming rough for a time. Southwest swell 2 metres easing. Northwest swell 1 metre developing. Poor visibility in rain developing during the afternoon.
OUTLOOK FOLLOWING 3 DAYS: Becoming Thursday morning northwest 40 knots. Changing late Friday southwest 40 knots then easing late Saturday to 30 knots. Very rough sea easing late Saturday. Moderate northwest swell easing Friday. Southwest swell becoming heavy Saturday.



Mean sea level analysis for 19 June 2007 1800 NZST

On 20 June 2007 at 1238 NZST, the MetService coastal forecast for the area of Raglan valid until midnight 21 June was as follows:

RAGLAN

GALE WARNING IN FORCE

Northeast rising to 35 knots early afternoon, easing to northerly 20 knots this evening. Becoming westerly 40 knots Thursday evening, easing to 30 knots at night. Sea very rough at times. Southwest swell 1 metre. Northwest swell 2 metres developing. Poor visibility in rain this afternoon and showers tomorrow.

OUTLOOK FOLLOWING 3 DAYS: Rising Friday morning to northwest 40 knots, changing late Friday morning southwest, easing late Saturday to 30 knots . Sea very rough for a time. Moderate northwest swell easing Friday. Southwest swell becoming heavy Saturday.

STEPHENS

GALE WARNING IN FORCE

West of Cape Egmont to Cape Farewell: Northeast 25 knots rising to 35 knots this afternoon then easing to 20 knots tonight. Elsewhere: Easterly rising to 25 knots this afternoon then easing to southeast 15 knots tonight. Becoming northwest 20 knots everywhere in the morning, rising to 30 knots but 40 knots in the west Thursday evening. Sea very rough in the west at times. Southeast swell in west 1 metre. Northwest swell 2 metres developing. Fair visibility in rain at times.

OUTLOOK FOR FOLLOWING 3 DAYS: Becoming Friday morning southwest 35 knots, rising Friday evening to westerly 45 knots with high sea, easing Saturday to 35 knots and Sunday in the east to southwest 25 knots. Moderate northwest swell easing Sunday. Southwest swell in west, becoming heavy early Saturday.

At 1304 NZST on 20 June MetService issued a bulletin for New Zealand coastal waters as follows:

SITUATION AT 1200 NZST ON 20 June 2007~
A deep low over the Tasman Sea is moving southeast with its associated fronts crossing northern and central New Zealand today and early Thursday. The low is expected to cross the upper South Island during Thursday, followed by a southwest flow which should become very strong on Friday, then start to ease during Sunday.

On 21 June at 1300 the *Taharoa Express* departed Taharoa for Tasman Bay. At 0922 NZST that day, the MetService coastal forecast for the areas of Raglan and Stephens valid until midnight 21 June was as follows:

RAGLAN

GALE WARNING IN FORCE

Northwest 20 knots rising to westerly 40 knots late afternoon, then easing to 30 knots tonight. Sea becoming very rough for a time. Northwest swell rising to 2 metres. Southwest swell 1 metre. Poor visibility in the showers this evening.

OUTLOOK FOLLOWING 3 DAYS: Rising Friday morning to northwest 40 knots, changing late Friday morning southwest, easing late Saturday to 30 knots. Sea very rough for a time. Moderate northwest swell easing Friday. Southwest swell becoming heavy Saturday.

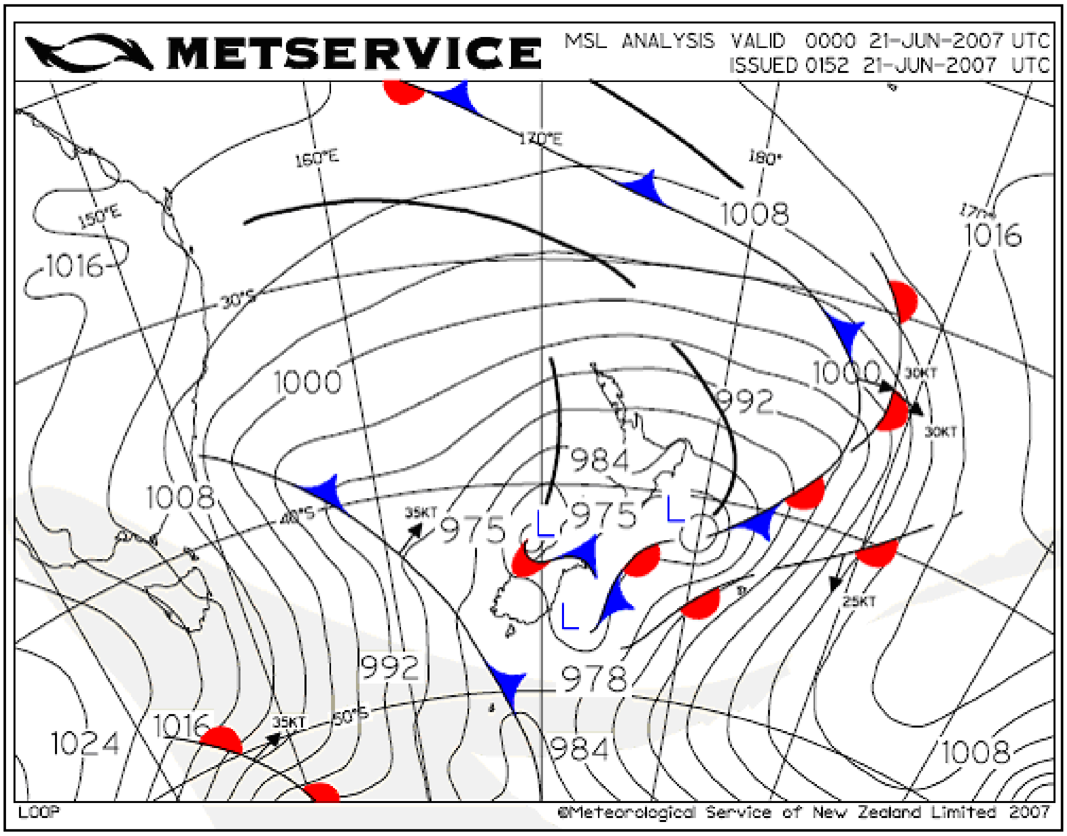
STEPHENS

GALE WARNING IN FORCE

Northwest 15 knots rising to 30 knots this afternoon and to westerly 40 knots early evening. Sea becoming very rough. Northwest swell rising to 2 metres. Southwest swell 1 metre.

Poor visibility in evening showers.

OUTLOOK FOLLOWING 3 DAYS: Becoming Friday morning southwest 35 knots, rising Friday evening to 45 knots with high sea, easing Saturday to 35 knots and Sunday in the east to southwest 25 knots. Moderate northwest swell easing Sunday. Southwest swell in west, becoming heavy early Saturday.



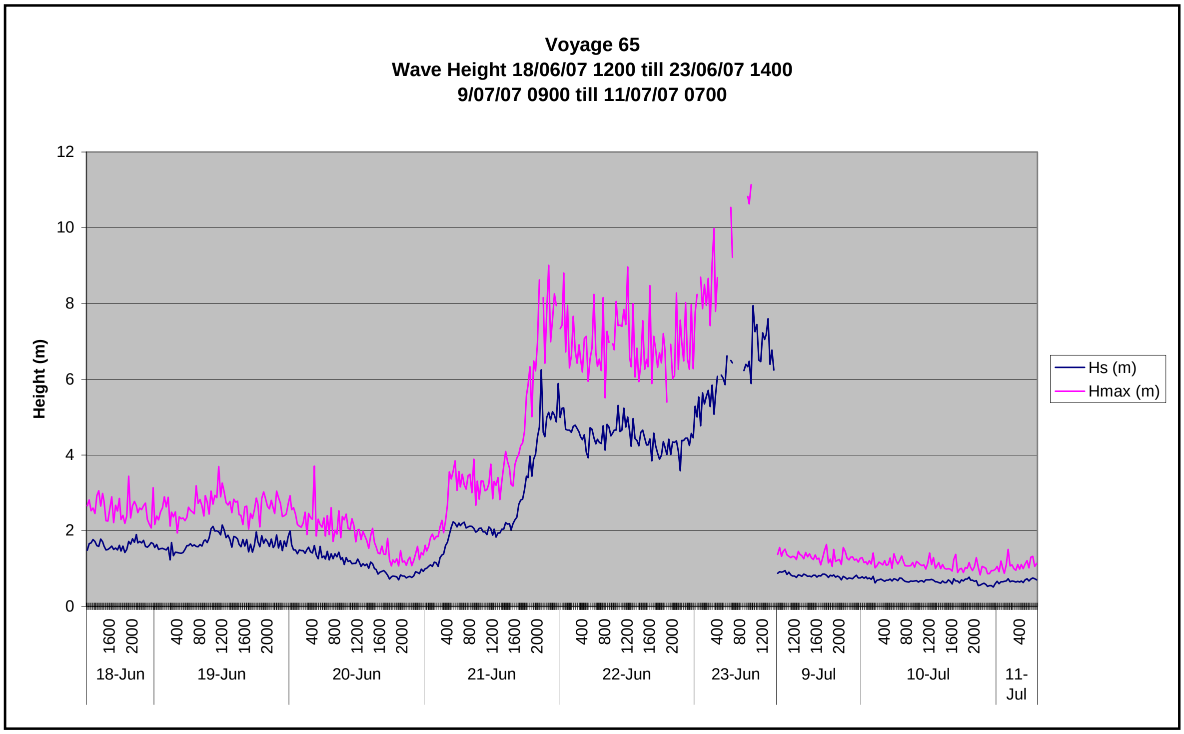
Mean sea level analysis for 21 June 1200 NZST

The wave rider buoy at Port Taharoa records in real time the significant and maximum wave heights so that conditions at the single buoy mooring are monitored to avoid the operating parameters of the buoy being exceeded.

The criteria for berthing operations at the single buoy mooring were set out in the sixth edition of the "operation procedure at Port Taharoa" manual on board the *Taharoa Express*. These were issued by the harbour master in a directive on 23 June 2004. The basic criteria are set out below.

> Maximum arrival berthing parameters for existing full time pilot is:
> A significant wave height of 3.0metres or a wind speed in excess of 30 knots.
>
> The vessel must depart the buoy if the swell at the wave rider exceeds 3.3 metres or the wind speed exceeds 40 knots.

Figure 12 shows the readings recorded during the period between noon 18 June and noon 23 June.



Swell data from Taharoa wave rider buoy

“Taharoa Express” Sloshing & Stability Investigation

ISSUE 7 – Final Report

"Taharoa Express"
Sloshing & Stability Investigation

Contents

Introduction

General

The bulk carrier “Taharoa Express” was part way through loading iron sand slurry at the Single Buoy Mooring (SBM) at Taharoa, New Zealand, when the loading process was stopped due to a flooded duct keel. Due to deteriorating weather the ship had to leave the SBM and the decision was made to seek a safe haven at Tasman Bay.

Numbers 1,3,5,7 and 9 cargo holds all contained part loads of iron sand with water on top. Number 6 cargo hold which was full of water ballast during the previous ballast voyage was still about 2/3 full at the time of the incident (the operating instructions on board state number 6 ballast hold is to be full or empty when the ship is at sea). Other designated ballast tanks were also part full.

During the passage from Taharoa to Tasman Bay, the iron sand cargo shifted resulting in the ship listing to 22 degrees. The exact mechanism of this shift is not known but it appears to have happened in several stages. Cargo shifted in all the holds to some degree. Eventually the ship reached a safe anchorage.

At the request of the Transport Accident Investigation Commission (TAIC), BMT SeaTech Ltd has undertaken a sloshing analysis to assess the behaviour of the free water in the cargo holds and No.6 ballast hold, and a stability assessment to investigate the effect of the cargo shift and free water on the safety of the vessel.

Objective

The aims of the sloshing analysis are to consider the free water in Nos. 1,3,5,7 and 9 cargo carrying holds and the No.6 ballast hold in order to:

- Determine the forces on the internal structure
- Identify whether design criteria were exceeded
- Comment on the possible outcome to the ship on the day of the incident when the ship was on passage from Taharoa to Tasman Bay.

The objective of the stability assessment is to analyse the stability of the vessel accounting for the effects of free water and the cargo shift, and to comment on the overall safety of the vessel with respect to stability.

Vessel Details

The “Taharoa Express” is a 9 hold Bulk Carrier of 137,900 tonne deadweight. Originally named “Stellar Cape, she was built in 1990 by Hyundai Heavy Industries. Her Class approval by Nippon Kaiji Kyokai [Class NK] listed her with the following notation:

NK, NS*, Bulk Carrier, “Strengthened For Heavy Cargoes,

Hold No. 2, 4, 6 and 8 may be empty” and MNS*, MO.

Her principal dimensions are summarised in Table 1.

Length, BP	259.00 m
Length, scantling	259.20 m
Breadth, moulded	43.00 m
Depth, moulded	23.80 m
Draught, moulded (design)	16.60 m
Draught, moulded (scantling)	17.40 m

Table 1: Ship Main Particulars

The ship was converted in 1999 to carry iron sand that is loaded as slurry and discharged conventionally. Each hold is loaded in two or more stages. Once the slurry is in the hold, the iron sand settles quickly out of the slurry and water remains above the sand. This supernatant water is drained through an overflow channel or valves into an overflow recess from where it is discharged overboard using the ship’s overflow pumps.

In the normal course of events the free water above the sand is removed before the ship sails, while further dehydration takes place on passage to the discharge port to reduce the water content to around 3%.

Loading Condition

The loading condition taken for this assessment is summarised below:

Condition No. 26 (From Loading Calculation Program)
Draught = 12.49 m Midships
Displacement = 113,949 tonnes

Total Ballast = 20,653 tonnes
No.6 Ballast Hold 11,469 tonnes (60% full)

Total Cargo Mass (Iron Sand & Water) = 72,624 tonnes

Cargo Hold	Total Cargo Mass (Loading Computer) [tonnes]	Iron Sand (dry) [tonnes]	Estimated Free Water [tonnes]
1	10,554	8,394	1,148
3	17,474	11,453	4,042
5	13,813	5,889	6,915
7	16,422	12,098	3,930
9	14,361	9,069	2,614

Table 2: Cargo Hold Contents

Sloshing Assessment

The forces on the internal structure due to fluid sloshing are governed by many different factors, including:

- The shape and position of the hold/tank
- The dimensions of the hold
- The fluid fill level
- The natural frequency of wave motion of the fluid
- The frequency and amplitude of the ship's motions

The sloshing phenomenon can generate considerable impact pressures on hold walls and ceilings when the excitation is near the natural frequency of the fluid. Consequently the following approach was used in the assessment:

Approach

1. The motion characteristics of the vessel in regular sea conditions were determined for a range of relative wave headings and frequencies at the passage speed.

2. The motion characteristics of the vessel were then used to determine the range of the ship's motions (e.g. roll, pitch, heave etc) for the sea conditions at the time of the incident.

3. Analytical formulae were used to estimate the natural frequency of the fluid in Number 1,3,5,7 and 9 cargo carrying holds and the Number 6 ballast hold for the specified cargo and fluid fill levels.

4. The natural frequency of wave motion of the fluid was compared with the frequencies and amplitudes of the vessel motions to evaluate the risk of resonance (and hence possible high impact pressures).

5. For the higher risk cases identified, a sloshing analysis was undertaken to calculate the maximum sloshing pressures on the hold/tank structure.

6. The calculated sloshing pressures were compared to the Class design criteria to identify any areas that are exceeded and comment made on the possible outcome to the vessel's structure.

Ship Motions

Ship Motion Characteristics

In order to establish the sloshing characteristics of the cargo in the holds, it is necessary to calculate the hydrodynamic characteristics (known as the Response Amplitude Operators, RAOs) for the "Taharoa Express". The linear 3D diffraction software PRECAL was used to calculate the 6 degree of freedom motion RAOs and acceleration RAOs at specific locations within the holds for the loading condition prior to the cargo shifting.

Ship Motion Model

PRECAL uses the panel method to discretise the hull form into panels (shown in Figure 1). The program calculates the velocity potentials, source strengths and flow velocities of the hydrodynamic mesh. Utilising potential flow theory the hydrodynamic forces are calculated in three dimensions which takes into account of forward speed.

Roll motion is very sensitive to the level of viscous damping (which is a summation of bilge keel and hull turbulent effects), but this is not calculated automatically by the program. A damping factor of 0.1 was used in the analysis: this gives a reasonable roll period and amplitude close to the observed motion. It is recognised that the damping factor is difficult to quantify precisely but the value used is indicative of this hull and bilge form.

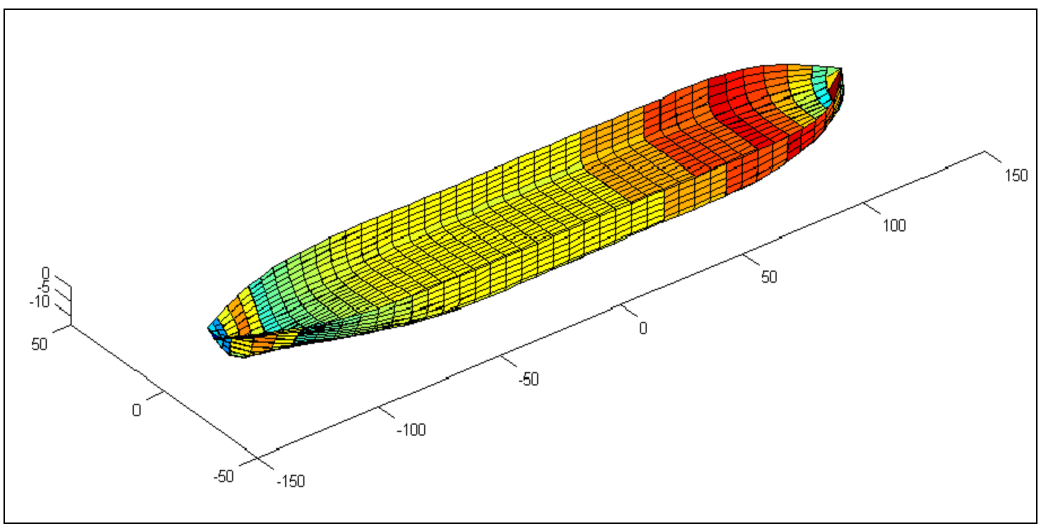


Figure 1: Hydrodynamic Mesh of Hull Form

Sea Conditions

Weather forecasts for New Zealand coastal waters [1] and wave buoy measurements at Taharoa [2] were provided by TAIC. The forecast identified distinct northwest and southwest swell components, which correspond to beam and head seas, respectively for the passage down the coast of North Island. The measurements made at Taharoa show good correlation with the forecasts (see Figure 2) and are used to estimate periods of encounter and wave directions. The wave periods at departure are between 6 to 8 s, but increase to 10 to 14 s in the early hours of 22 June.

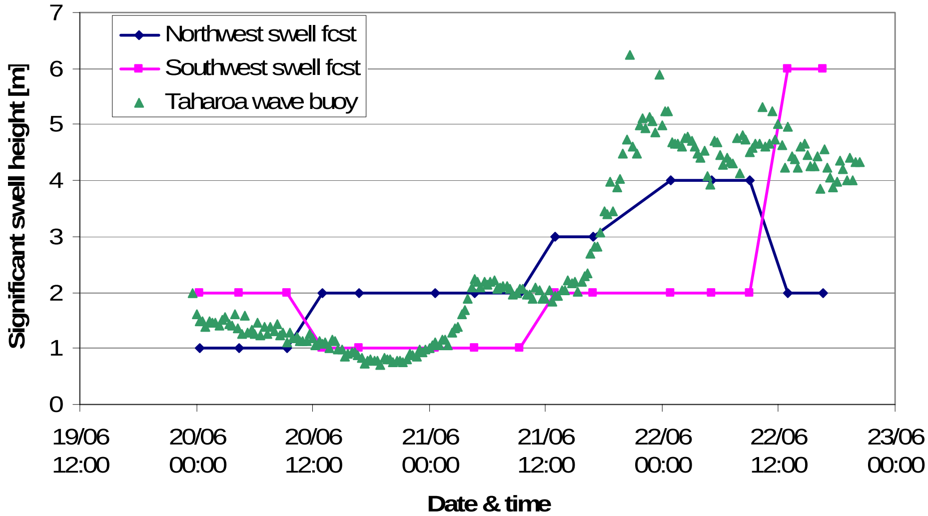


Figure 2: Forecast and Observed Swell Height along the Route of "Taharoa Express"

The distribution of swell direction relative to the heading of the "Taharoa Express" (Figure 3) is shown in Figure 4. The most significant components are between 90-100 deg (beam seas) and 130-140 deg (quartering seas). The distribution of encounter periods in Figure 5 peaks at 5 s and a further peak between 8 and10 s.

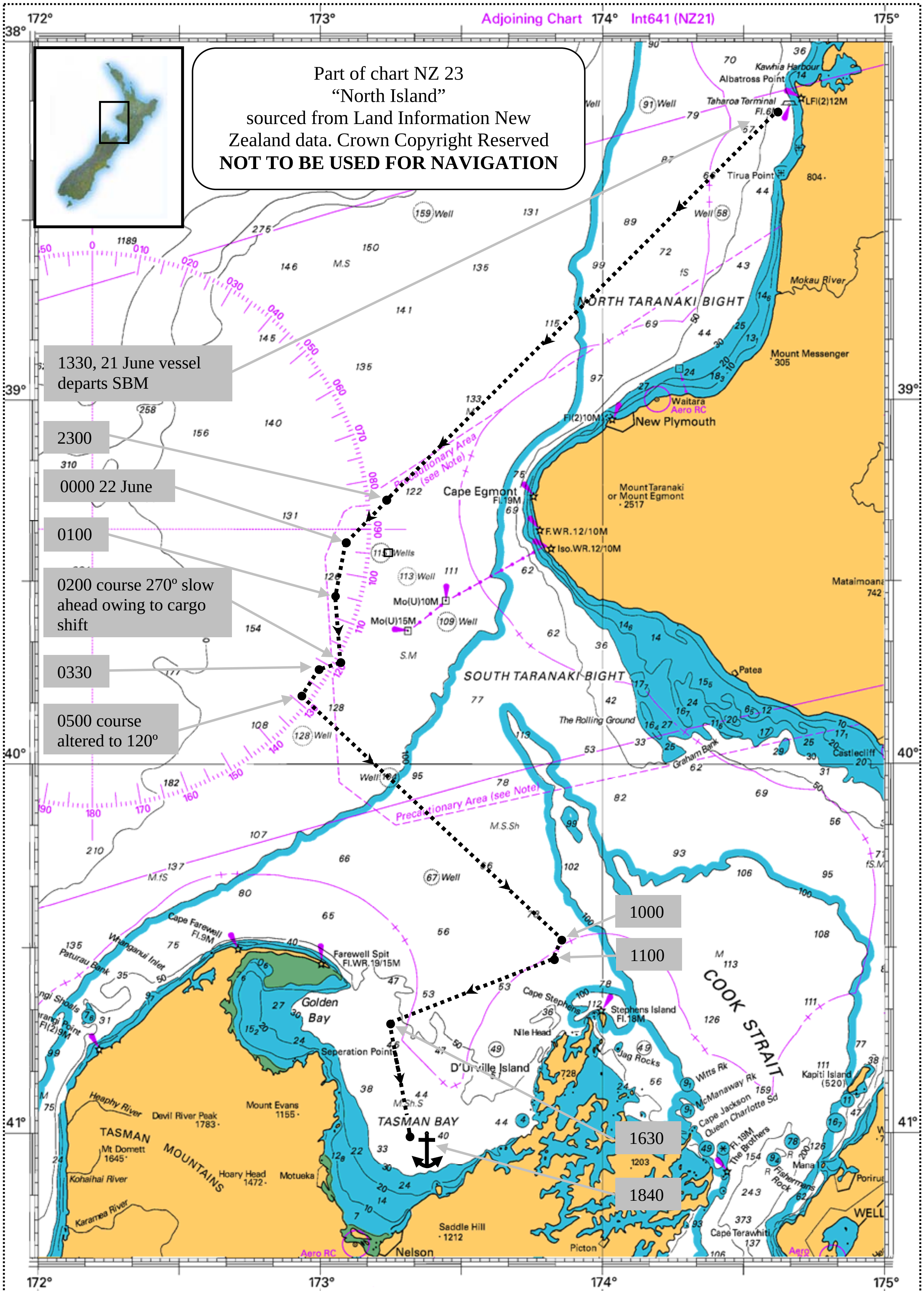


Figure 3: Vessel Route from Taharoa to Tasman Bay

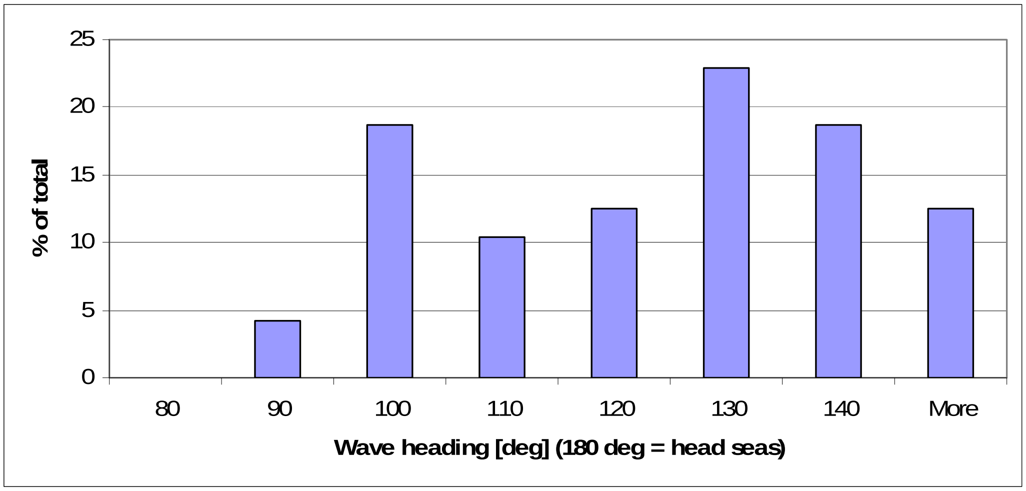


Figure 4: Wave Direction Following Emergency Departure from Taharoa Terminal

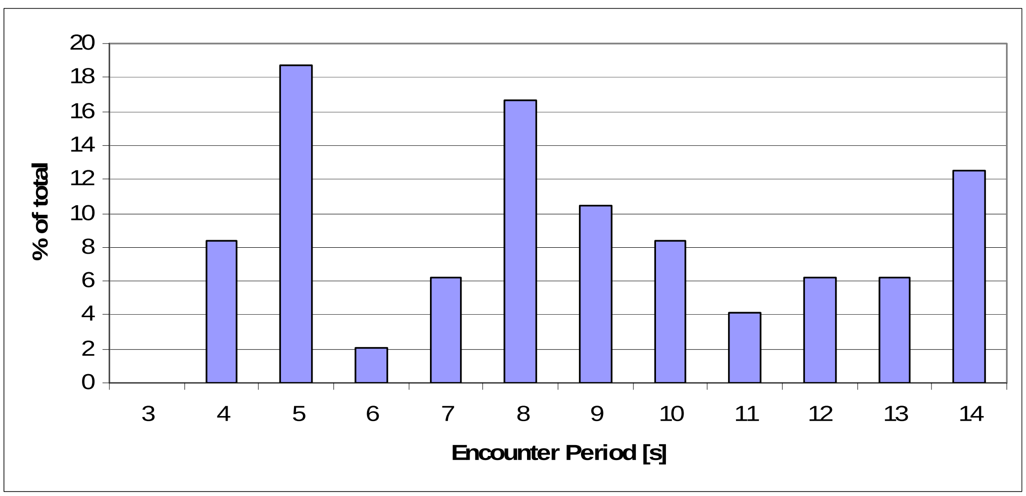


Figure 5: Period of Wave Encounter Following Emergency Departure from Taharoa Terminal

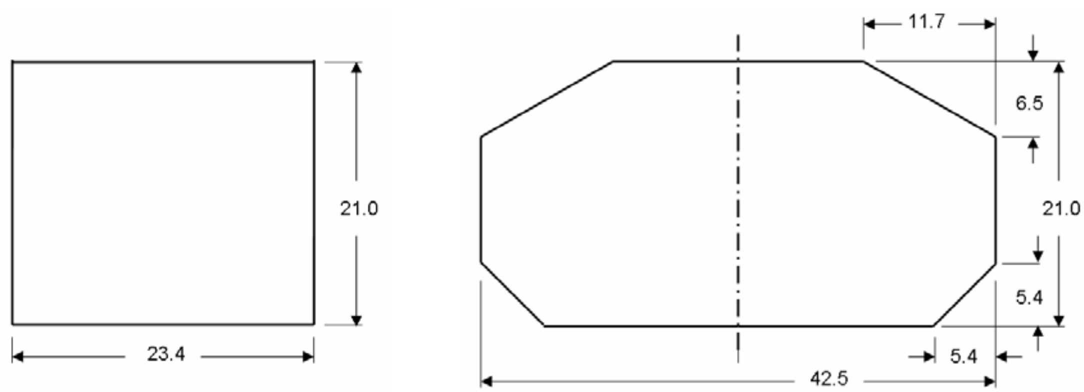
Sloshing Analysis

Natural Frequencies

Sloshing occurs when a hold partially filled with fluid is subjected to a motion. The sloshing response depends on:

- the properties of the fluid (density, viscosity)
- the shape of the hold
- the magnitude and frequency of the excitation force
- the previous sloshing flow

In a clean hold containing a liquid with small kinematic viscosity, the proximity of the excitation frequency to the resonant frequency is the main factor determining the sloshing severity.



6(a) Longitudinal Cross Section *6(b) Transverse Cross Section*

Figure 6: Cross-Sections of Cargo Holds (all dimensions in m)

The cargo holds contain iron sand slurry and water. It is assumed that the iron sand remains at the bottom of the hold and does not influence the sloshing behaviour. The iron sand negates the effect of the lower hopper tank on the resonant sloshing frequency. Therefore, both the transverse and longitudinal cross sections of the hold can be treated as rectangular.

The natural sloshing period of a rectangular container is given as

$$T_m = 2 \cdot \pi \cdot \frac{1}{\sqrt{g \cdot k \cdot \tanh(k \cdot h)}}$$

With

$$k^2 = \pi^2 \left(\frac{m^2}{a^2}\right)$$

where *a* is the length of the sloshing container (hold length for longitudinal sloshing, hold breadth for transversal sloshing), *g* gravity, *h* filling level and *m*=1,2,3,... . The first sloshing mode (m=1) is the most critical with approximately 90% of the effective sloshing mass [3]. As a precaution, the second resonance condition is sometimes assessed in vessels where sloshing is a principal design criterion.

The resonant period and the type of sloshing response depend on the ratio of filling height to hold length. When this filling ratio is above 0.3-0.4, the sloshing fluid behaves as a standing wave and the critical hold motions are angular (i.e. roll and pitch). In this case, the fluid impacts usually occur at the top of the hold [4]. When the filling ratio is below 0.3-0.4, a travelling wave (sometimes referred to as a hydraulic jump or bore) develops. This travelling wave is most severe at filling ratios of 0.1-0.3, and impact pressures can be several magnitudes greater than the static pressure. Sloshing at low filling levels is more susceptible to linear hold motions such as sway and surge. No.5 cargo hold and No.6 ballast hold are in this critical region (see Table 3).

The first and second resonant sloshing periods for each hold are given in Table 3. The first resonant periods in the transverse direction range between 8.6 s and 21 s. In the longitudinal direction, the range is between 5.7 s and 11.9 s. These sloshing resonance periods are within the region of swell periods observed during the voyage on 21-22 June.

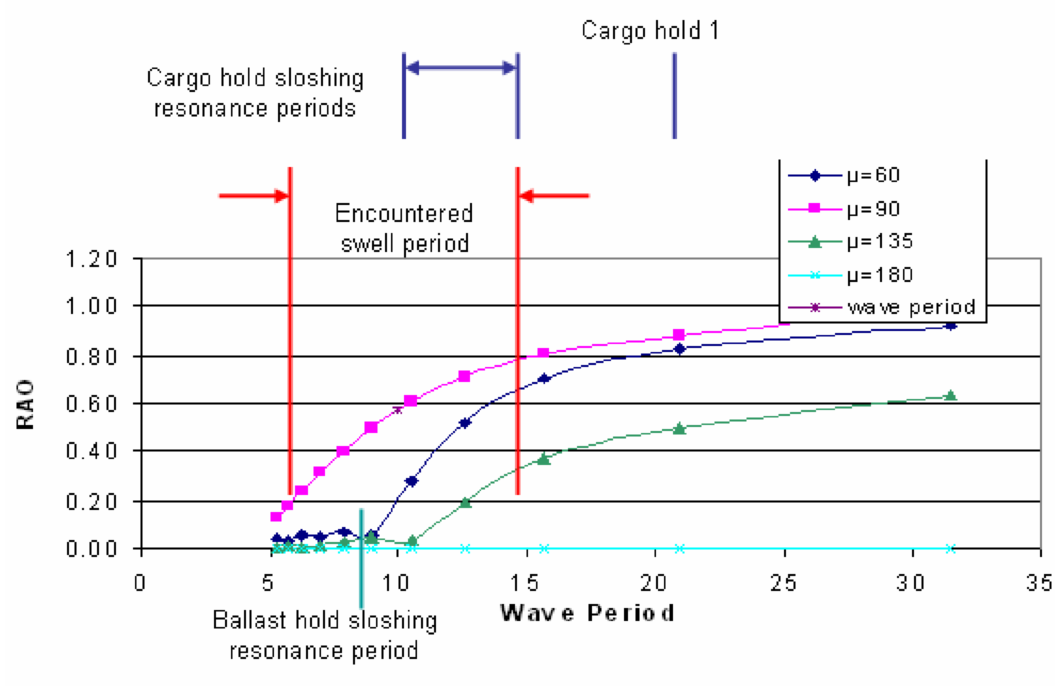
Cargo Hold	Free Water Height [m]	h/L	Sloshing Resonant Period			
			Longitudinal		Transverse	
			1st Mode [s]	2nd Mode [s]	1st Mode [s]	2nd Mode [s]
1	1.6	0.04	11.9	8.4	21.5	15.2
3	4.5	0.11	7.4	5.3	13.0	9.2
5	7.7	0.18	6.2	4.4	10.3	7.3
7	4.4	0.10	7.5	5.3	13.2	9.3
9	3.5	0.08	8.3	5.8	14.7	10.4
6 (Ballast)	12.8	0.30	5.7	4.0	8.6	6.1

Note: the free water height figures were provided during the early stages of the investigation. Updated information suggests that the free water heights may differ slightly from these figures. The revised data is not considered to significantly affect the results of the sloshing assessment and so the original figures have been retained.

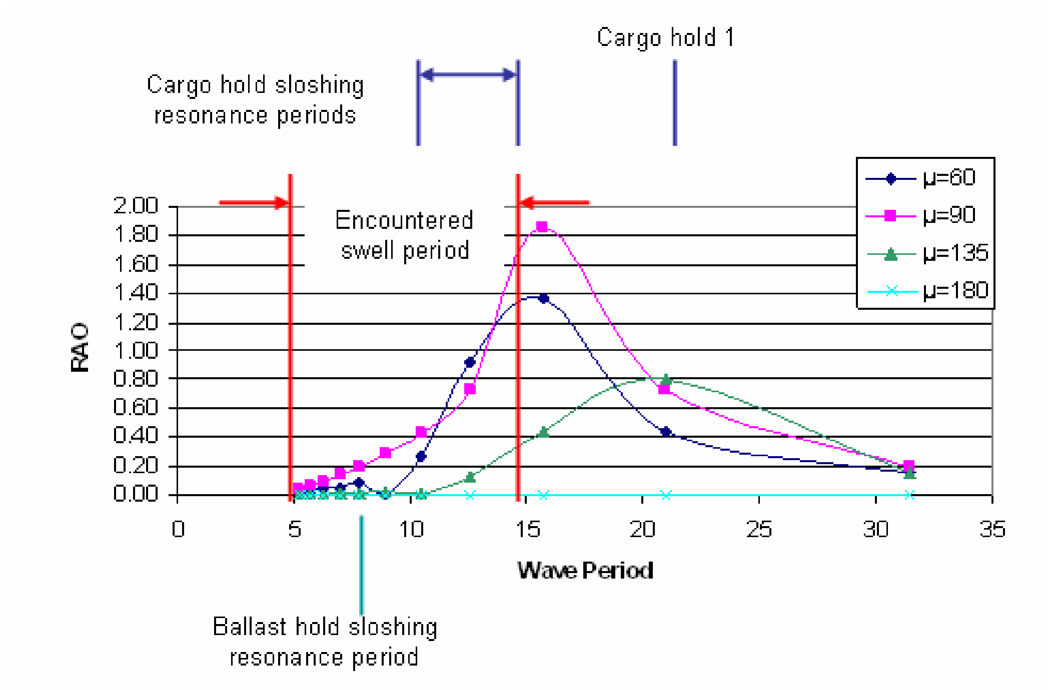
Table 3: First and Second Natural Sloshing Frequencies

The comparison of the sloshing resonant frequencies with the range of likely ship motions is a first pass to determine the probability of severe sloshing. The ship motions are characterised by the response amplitude operators (RAOs). Figure 7 shows the RAOs of the transverse motions of the "Taharoa Express" compared to encounter wave periods. The main wave direction μ is between 90 and 100 deg and between 130 to 140 deg (see Figure 4).

- For sway, the encountered waves result in vessel motion amplitudes large enough to cause sloshing at the first resonant period.
- The peak of the roll RAOs is near the resonant sloshing period of the cargo holds, with a peak roll amplitude of about 6 deg.
- Lateral accelerations are approximately 0.1*g* for a 5 m wave height (see Figure 8) and 0.08 *g* for a 3 m wave height. The maximum acceleration occurs near the resonant sloshing periods calculated previously.



Sway



Roll

Figure 7: Response Amplitude Operators and Sloshing Resonance for Transverse Motions

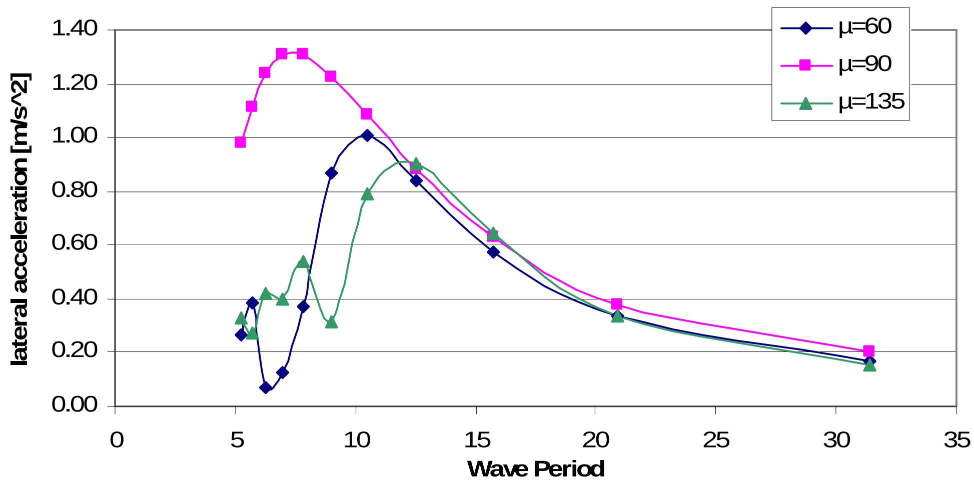
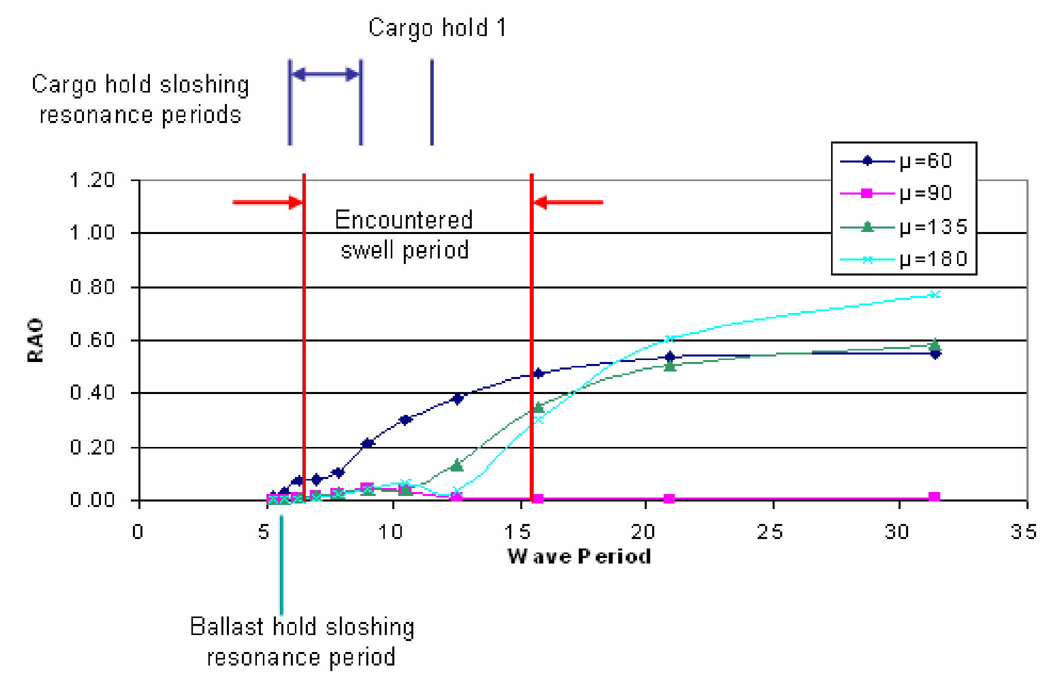


Figure 8: Lateral Accelerations at 12 knots with 5m Significant Wave Height

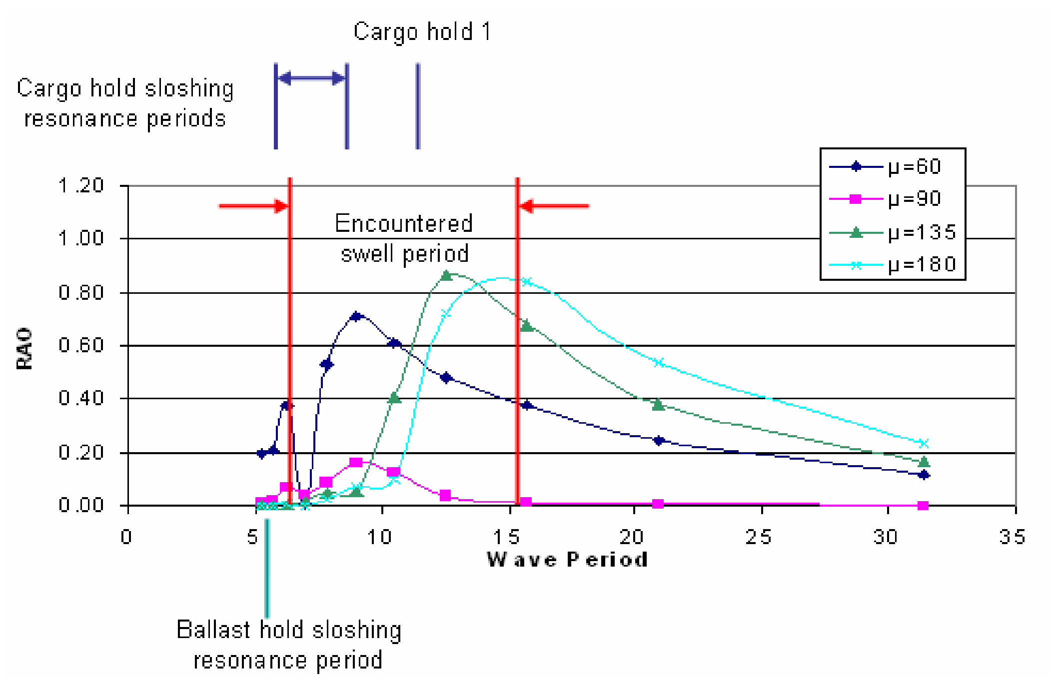
- The surge RAO (Figure 9) near the sloshing resonance periods is several times smaller than the sway RAO.
- Pitch motions are significant, but their significance on the sloshing response is less than linear motions.

To identify the high risk cases warranting further analysis, the first consideration is the magnitude of the RAO at the sloshing resonant periods. This is found to be significant for both sway and roll. For surge and pitch, the RAO at the sloshing resonance periods was far smaller. Secondly, the sloshing resonant periods are well within the range of encountered wave periods for the transverse vessel motions. In the longitudinal case, there is considerably less overlap between the sloshing resonant periods and the encountered swell periods. The nature of the motion (linear or angular), the hold shape and filling level also affects the sloshing response. For the present hold conditions, the linear hold motions tend to result in the most severe sloshing. Therefore, the most severe sloshing response was caused by sway. The sloshing response due to roll was found to be less significant. Neither longitudinal motion resulted in the severe sloshing observed in the analysis of the transverse motions.

No.5 cargo hold and No.6 ballast hold have the most critical filling ratios. A detailed numerical analysis now focuses on these two holds.



Surge



Pitch

Figure 9: Response Amplitude Operators and Sloshing Resonance for Longitudinal Motions

Sloshing Pressures

The numerical investigation is carried out with the software package LR Fluids. It is intended for use in the design of vessels such as LNG carriers, where sloshing is a key concern. LR Fluids is based on the marker-and-cell method. Only the fluid is simulated, which increases the computational efficiency, but there are some limitations when dealing with fluid impacts. The computational parameters used are summarised in Appendix A.

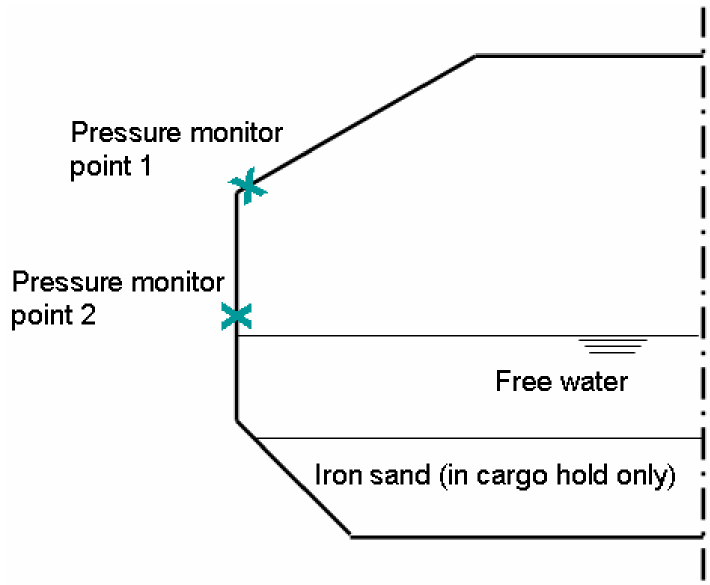


Figure 10: Location of Pressure Monitor Points on Transverse Hold Cross Section

It was found that the most violent sloshing occurs in the transverse hold direction with sway motions. Figure 10 shows the location of the pressure monitor points and the initial problem conditions. Monitor point 1 is located at the foot of the upper hopper tank, where the most severe impact pressures are expected [5]. The second monitor point is located at the side shell just above the initial free surface elevation. The iron sand in the cargo holds is assumed to remain stationary and it is not included in the simulation.

<u>Cargo Hold No.5</u>

Cargo hold No.5 contains 5,889 tonnes of iron sand and 6,915 tonnes of free water. This corresponds to a cargo height of approximately 2 m and a free water height of 7.7m. This gives a filling ratio of 0.18, which is above the threshold in [6]. The worst case scenario analysed uses a significant wave height of 5 m, which corresponds to a sway amplitude of 2.8 m. The sloshing motion is excited at the first natural sloshing period of 10 s.

The impact pressures at the foot of the upper hopper tank in Figure 11 are about 15 times greater than the static pressure. The peak pressure magnitudes vary between 1,000 and 1,500 kN/m^2.

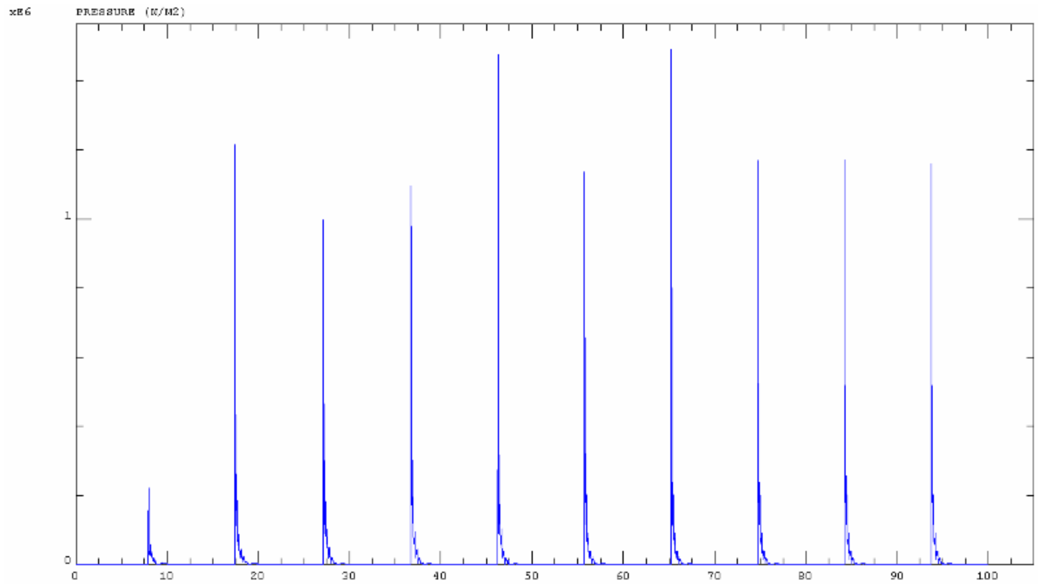


Figure 11: Pressure History at the Hopper (Point 1) During Transverse Sloshing at Resonance. Pressure in MN/m²

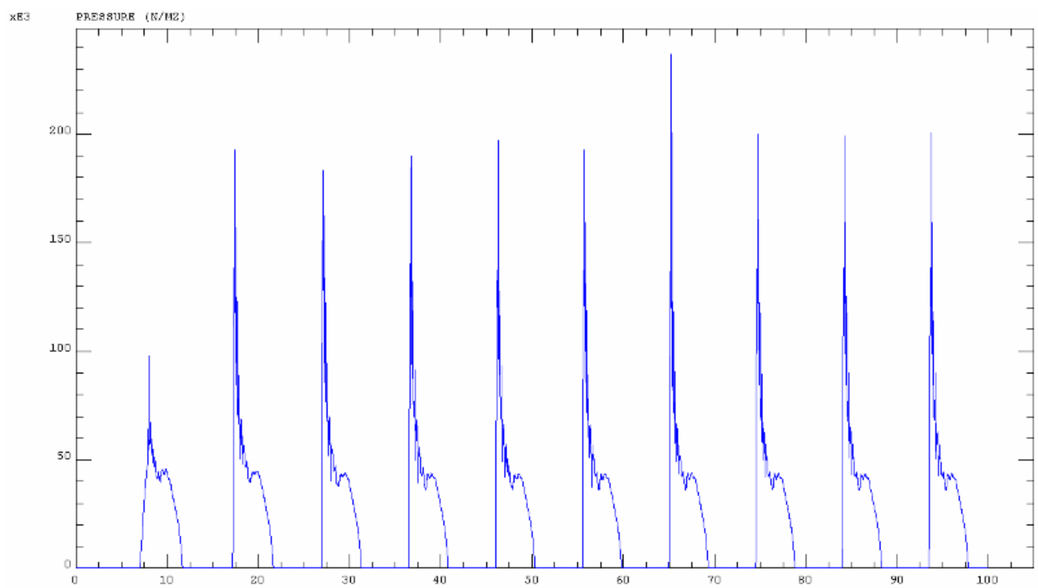


Figure 12: Pressure History at the Side Shell Centre (Point 2). Pressure in kN/m²

The sequence of a typical sloshing impact is shown in Figure 13, where the white arrows indicate mean flow fields. The travelling wave moving towards the hold side wall is seen in Figure 13a. Water is directed upwards by the lower hopper. In Figure 13b, the travelling wave has reached the side wall. Subsequently the jet shown in Figure 13c forms travels directly toward the upper hopper with a velocity of approximately 20 m/s. The jet has reached the onset of the hopper tank and the initial impact is visible in Figure 13d and 13e, with the main impact occurring in Figure 13f. From the point of impact, a pressure pulse in excess of the static pressure propagates into the fluid and along the side shell. The maximum impact pressure in this sequence is 860 kN/m² and the duration of the impact between Figures 13d and 13f is approximately 0.15 s. Once the jet is deflected, the pressure drops off (in Figure 13g) and the flow is moving along the hopper, as shown in Figure 13h.

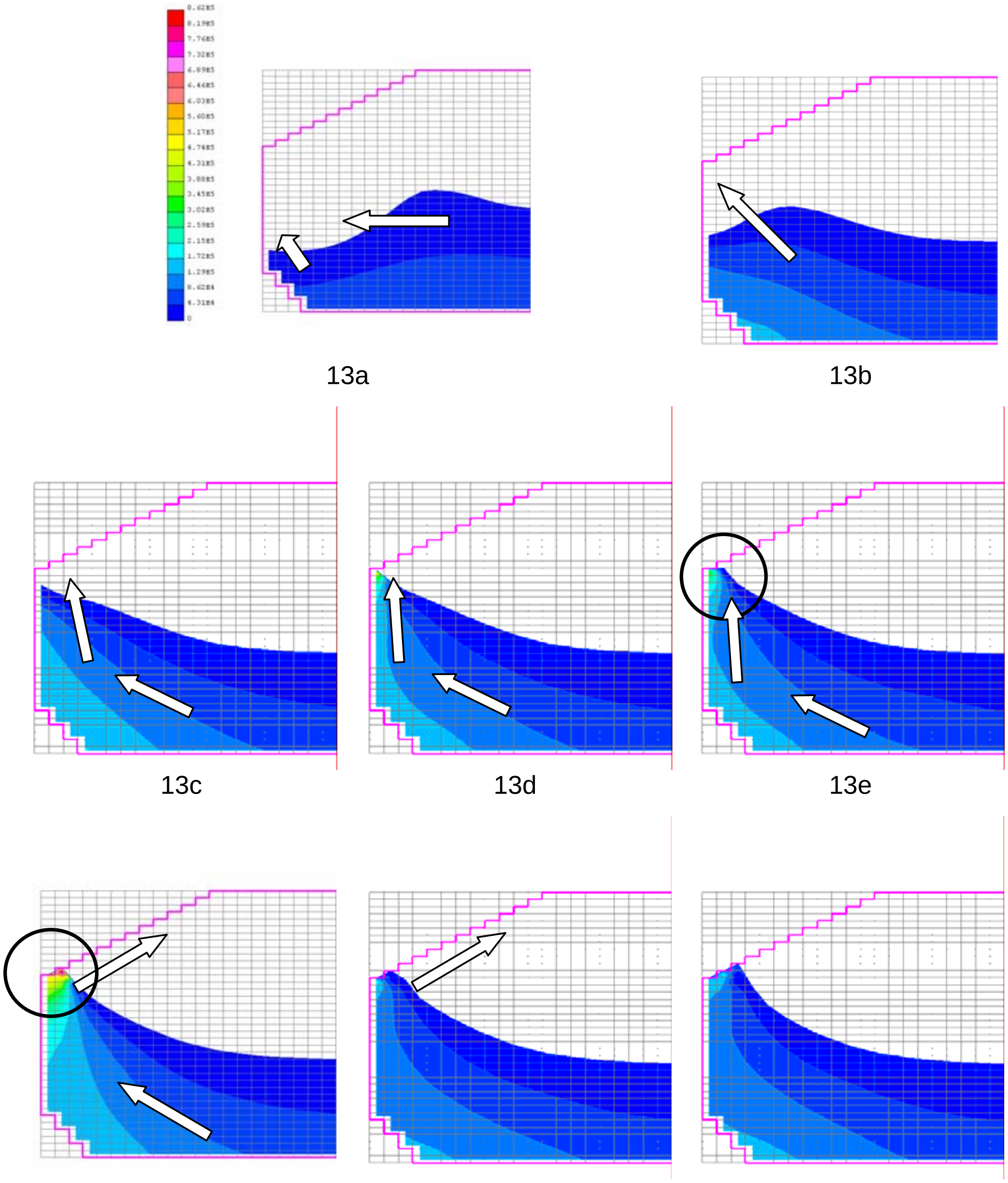


Figure 13: Impact Pressure Evolution in Cargo Hold No.5

Ballast Hold No.6

Ballast hold No.6 is filled up to 12.8 m of water, which corresponds to a filling ratio of 0.30. This tends to be in the critical region where violent sloshing is expected. Figures 14 and 15 show the pressure history for the first resonant sloshing period of 8.6 s at monitor points 1 and 2, respectively. The pressures follow a similar behaviour as in cargo hold No.5. The impact sequence in Figure 16 is also similar, although the travelling wave in Figure 16a is not as well defined as previously. The pre-impact jet velocity is slightly lower at 15 m/s, but the post-impact velocity is in excess of 30 m/s. The impact causes a pressure pulse to propagate into the fluid as shown in Figure 16c.

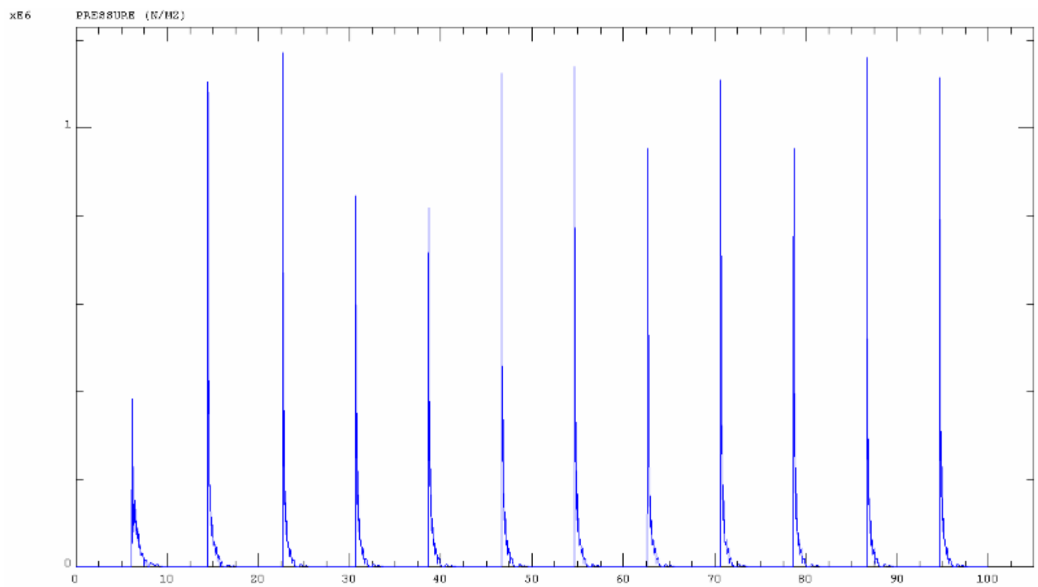


Figure 14: Pressure History at the Hopper (Point 1) During Transverse Sloshing at Resonance. Pressure in MN/m²

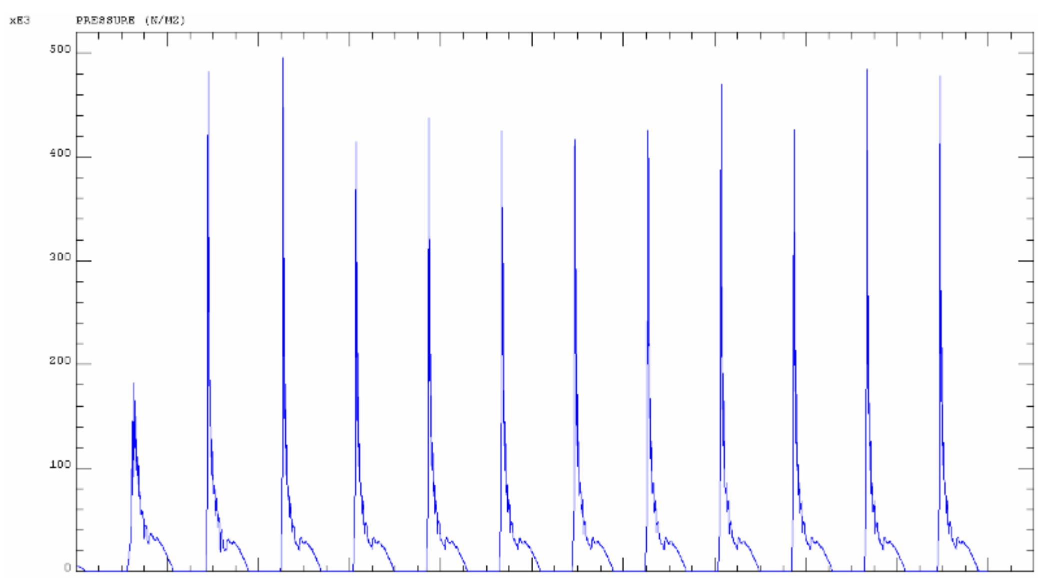


Figure 15: Pressure History at the Side Shell Centre (Point 2). Pressure in kN/m²

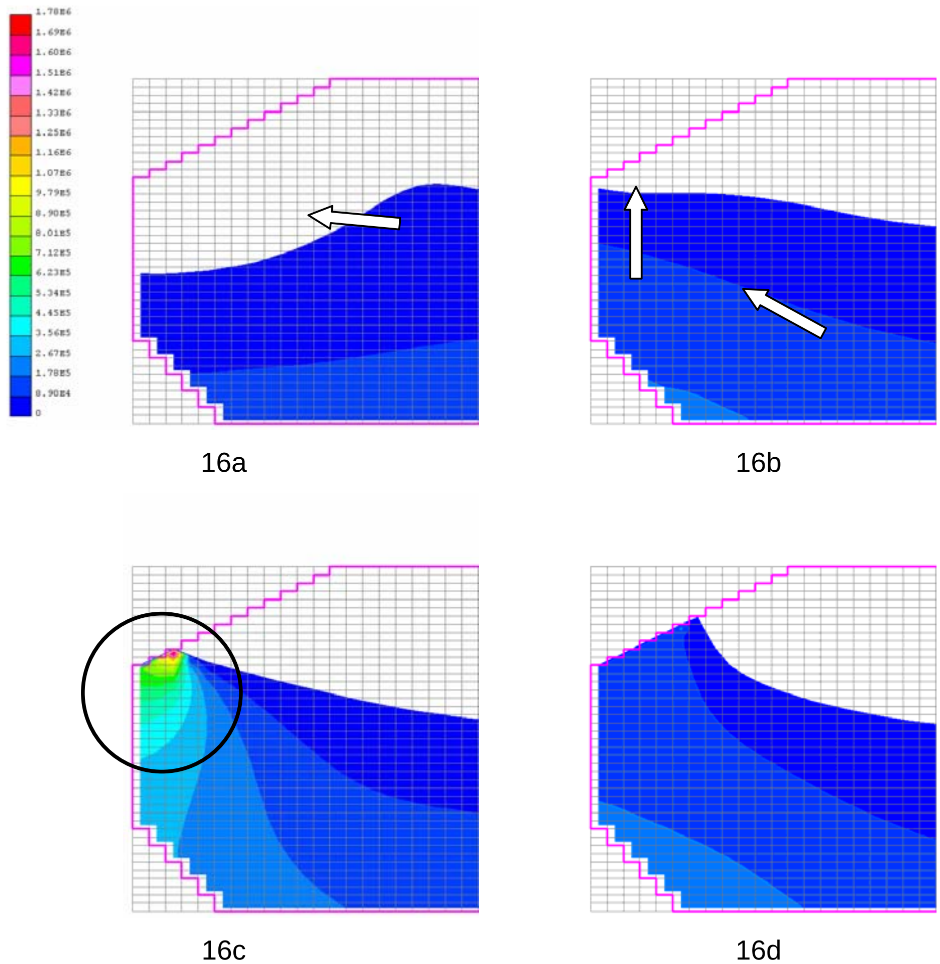


Figure 16: Impact Pressure Evolution in Ballast Hold No.6. The First Resonant Mode is Excited.

The excitation at the second resonant period of 6.1 s results in a considerably more severe sloshing response. Figures 17 and 18 show an increase of the impact pressure by up to an order of magnitude compared to the previous cases. However, when the swell was large (5 m), the swell period was usually closer to the first sloshing resonance. It is therefore highly unlikely that the second harmonic would be encountered, although the very short rise time and the possibility of quartering seas means that this condition cannot be completely discounted.

The severity of the impact pressure in this condition is explained by the impact sequence. Rather than forming a jet at the side wall, the fluid is moving directly towards the hopper (Figure 19a), while a secondary jet is moving up along the side wall. The initial impact magnitude is approximately 1,000 kN/m², which corresponds to a lower speed (12 m/s) but a direct impact. The resulting pressure pulse then directs part of the flow back towards the tank (Figure 19b), while a component of the flow is directed towards the foot of the upper hopper. These two flows impact the hopper simultaneously. This leaves no path to divert the oncoming flow and a much higher impact pressure results (see Figure 19c). The duration of this impact of about 0.1 s is slightly shorter than in the previous cases, but the non-uniform nature of the impact can result in significant fluid-structure interaction effects.

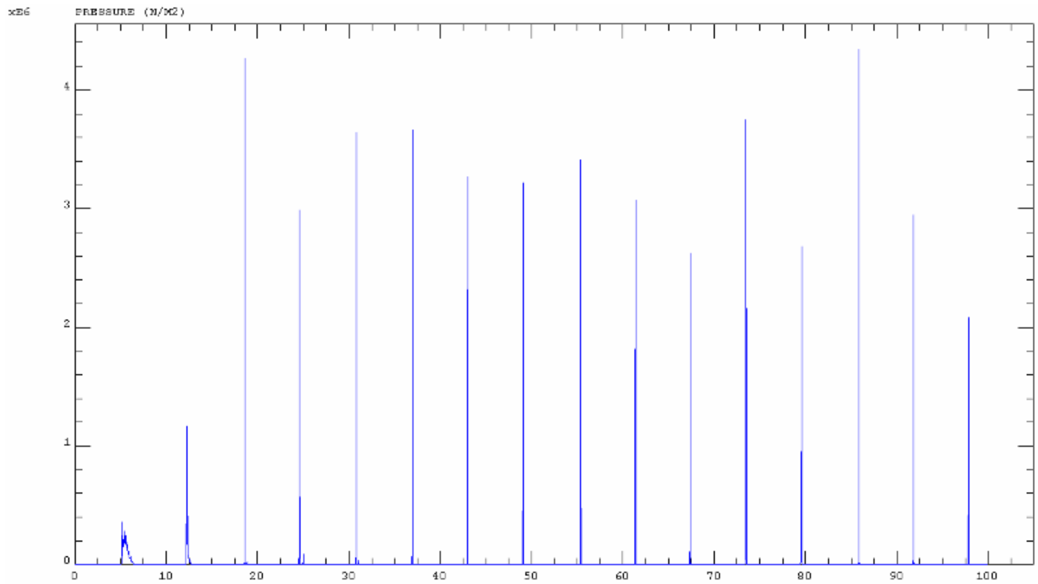


Figure 17: Pressure History at the Hopper (Point 1) During Transverse Sloshing at Resonance. Pressure in MN/m²

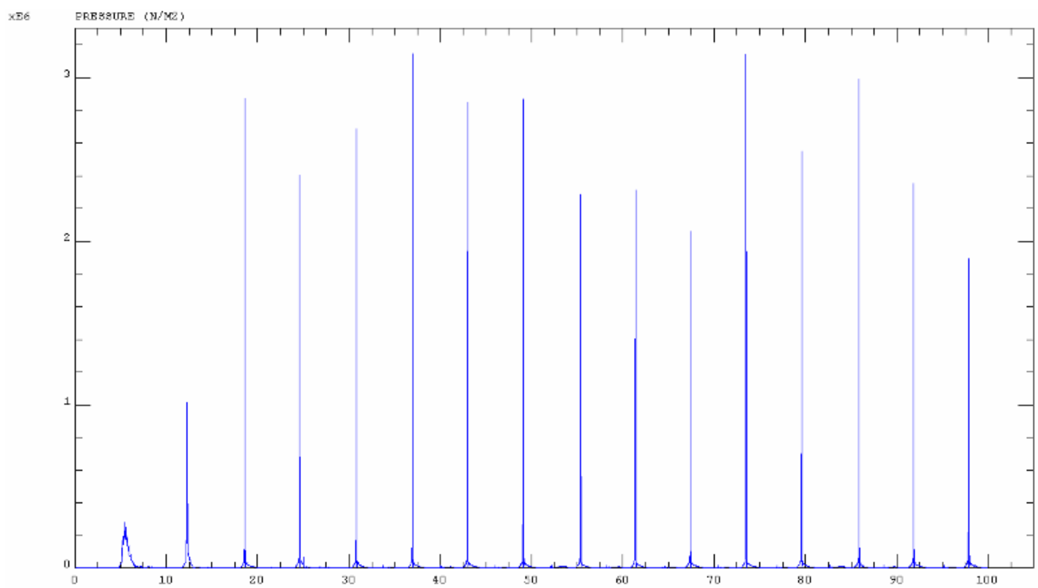


Figure 18: Pressure History at the Side Shell Centre (Point 2). Pressure in MN/m²

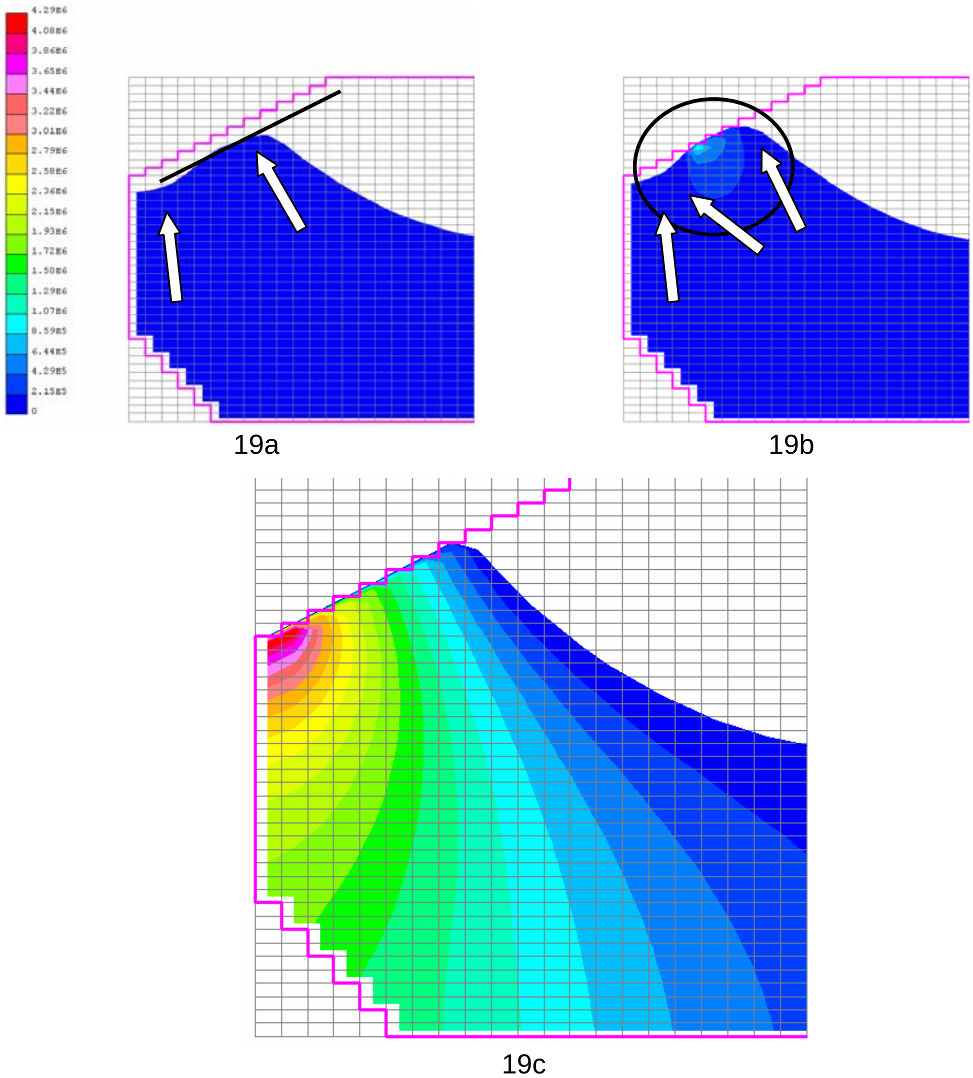


Figure 19: *Impact Pressure Evolution in Ballast Hold No.6. The Second Resonant Mode is Excited.*

Influence of Cargo Shift on Sloshing

The sloshing analysis has been conducted for the ship in an upright condition, with the iron sand cargo assumed level in the holds. Whilst these assumptions are generally applicable at the time the vessel left Taharoa SBM, during the passage to Tasman Bay the cargo shifted within the holds and the ship listed to an angle of 22 degrees. The likely influence of the ship listing and cargo shift on the sloshing pressures are as follows:

Effect of Ship List

- The ship list of 22 degrees leads to a reduction in the effective hold width, giving a slightly shorter transverse resonant period.
- For the shallower draft side of the vessel, it is likely that the sloshing pressures will be reduced, both on the side shell and at the upper hopper.
- For the deeper draft side of the vessel, the peak sloshing pressures would not occur at the lower end of the upper hopper (Point 1). However, it is possible that fluid impact may occur instead at the top of the hold / hatch of Ballast Hold No.6, although the pressures are not expected to be as severe.

Effect of Cargo Shift

- The cargo shift is not expected to have a significant effect on the magnitude of the sloshing pressures.

Sloshing Pressure Comparison

The Load on Bulkhead at Slurry Loading

The [Nippon Kohan K.K] NKK report “Load on Bulkhead at Slurry Loading” [11] details the rule loads on the transverse and longitudinal bulkheads of the cargo holds. These pressures are summarised below:

1. Pressure by Bulk Safety Rule:

   Maximum pressure on bulkhead (at bottom) for No.3 CH = 290 kN/m^2

   (Nos. 5 & 7 Holds similar)

2. Sloshing Calculation by DNV [Det Norske Veritas]Rule:

   Maximum sloshing pressure for No.3 CH (Nos. 5 & 7 Holds similar)

   - On Transverse Bulkhead 48 kN/m^2
   - On Longitudinal Bulkhead 149 kN/m^2

Sloshing Analysis

The sloshing pressures calculated in section 2.3.2 on the longitudinal structure due to transverse hold motion are summarised below. The pressures on the transverse bulkheads are not considered to be of concern as the assessment in section 2.3.1 showed that for the surge and pitch motions, the RAOs at the sloshing resonance periods were far smaller than for the sway and roll motions.

1. Cargo Hold No.5
   - Upper Hopper Tank 1000 – 1500 kN/m^2
   - Side Shell 200 - 240 kN/m^2

2. Ballast Hold No.6

   1st resonance mode

   - Upper Hopper Tank 1000 – 1200 kN/m^2
   - Side Shell 400 – 500 kN/m^2

   2nd resonance mode

   - Upper Hopper Tank 3000 – 4000 kN/m^2
   - Side Shell 2000 – 3000 kN/m^2

Comments

Preliminary structural calculations have been performed to provide an indication of the possible effects of the sloshing pressures on the hull structure:

- The hold frames in way of the high sloshing pressure has been assessed using simple beam theory.

- The hold plating has been assessed by using plastic analysis techniques. The collapse resistance of the plate in bending was calculated by means of yield line theory [12], with the assumption that a uniform lateral pressure is applied to the panel.

Further detailed calculations would be required to provide a definitive assessment of the structural response.

Cargo Hold No.5

- The pressures on the upper hopper tank are considerably in excess of those presented in the NKK report [11]. This is because the simplified calculations in the NKK report do not allow for fluid impact on the upper hopper tank.
- The sloshing pressures on the side structure of Cargo Hold No.5 are not considered high enough to breach the structural integrity of the hull.
- The sloshing pressure on the upper hopper tank may be sufficient to locally damage the structure if a severe sloshing response is encountered. Repeated fluid impact could cause the damage to become more widespread.

Ballast Hold No. 6

1st resonance mode:

- The pressures on the upper hopper tank and side shell are considerably in excess of those presented in the NKK report [11]. Again, this is because the simplified calculations in the NKK report do not allow for fluid impact on the upper hopper tank.
- The sloshing pressures on the side structure of Ballast Hold No.6 in the 1st resonant mode are not considered high enough to breach the structural integrity of the hull.
- As with the Cargo Holds No.5, the sloshing pressure on the upper hopper tank of Ballast Hold No.6 may be sufficient to locally damage the structure if a severe sloshing response is encountered.

2nd resonance mode

- This sloshing response generates very high sloshing pressures, although it is highly unlikely that this response would be encountered.
- The sloshing pressures on the side structure of Ballast Hold No.6 may be high enough to breach the structural integrity of the hull if the 2nd resonant mode occurred.

Ship Stability Assessment

Objectives

The loading computer on board the "Taharoa Express" was not capable of adequately calculating the stability of the vessel at the time of the incident. Firstly, the software was not able to determine the free surface correction to the GZ curve for the combination of iron sand and free water in the cargo holds. Secondly, it assumes a level cargo distribution and could not cater for the shift of the cargo to one side of the hold. The aim of the analysis presented in this section is therefore to re-assess the stability of the vessel accounting for the free water and the cargo shift, and to comment on the overall safety of the vessel with respect to stability.

Reduction in Stability due to Free Water

The GZ curve from the loading computer is reproduced in Figure 20. This GZ curve does not take account of the reduction in static stability caused by the free water in the cargo holds.

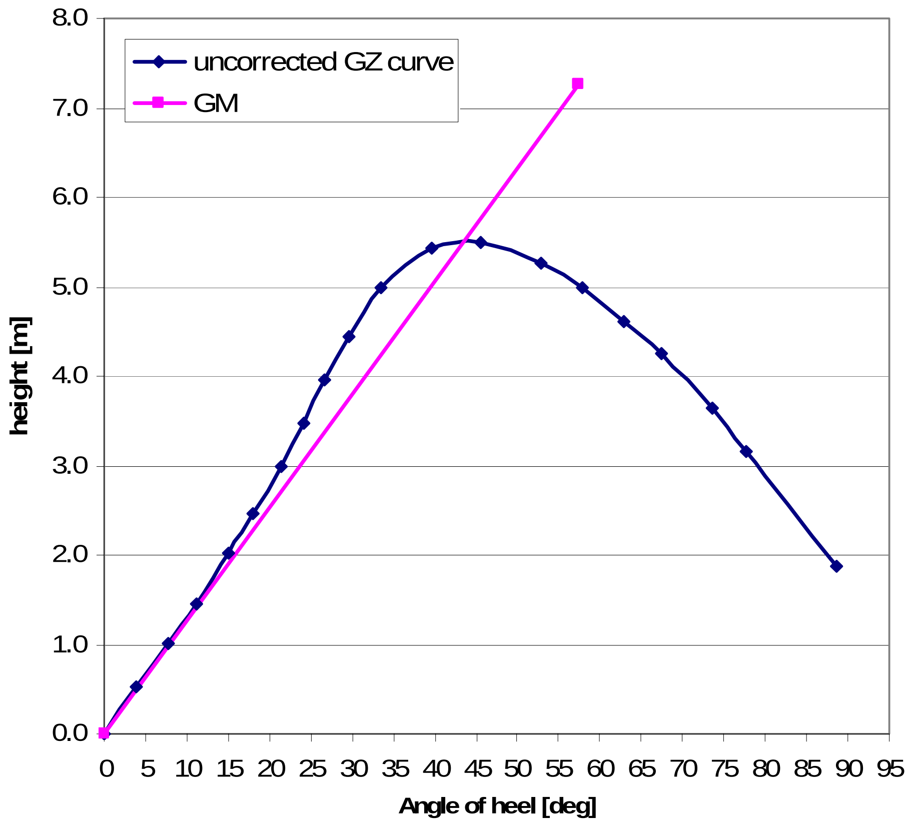


Figure 20: GZ Curve from Loading Computer
Not Corrected for Free Surface Effects (GM=7.27 m)

The GM is corrected for the effects of the free surface by calculating the moment of transference for the free water in each hold at various angles of inclination. The moment of transference is the product of the free water weight and the shift of the water's centre of gravity parallel to the inclined waterline.

The corrected GM is reduced to 2.2 m due to the effects of the free surface in the cargo holds, with the approximate shape of the corrected GZ curve shown in Figure 21.

The free surface corrections have been conducted for the ship in an upright condition, with the cargo level in the holds. The shift of the cargo to one side of the hold will further modify the free surface correction, resulting in an asymmetric GZ curve that differs between port and starboard inclinations.

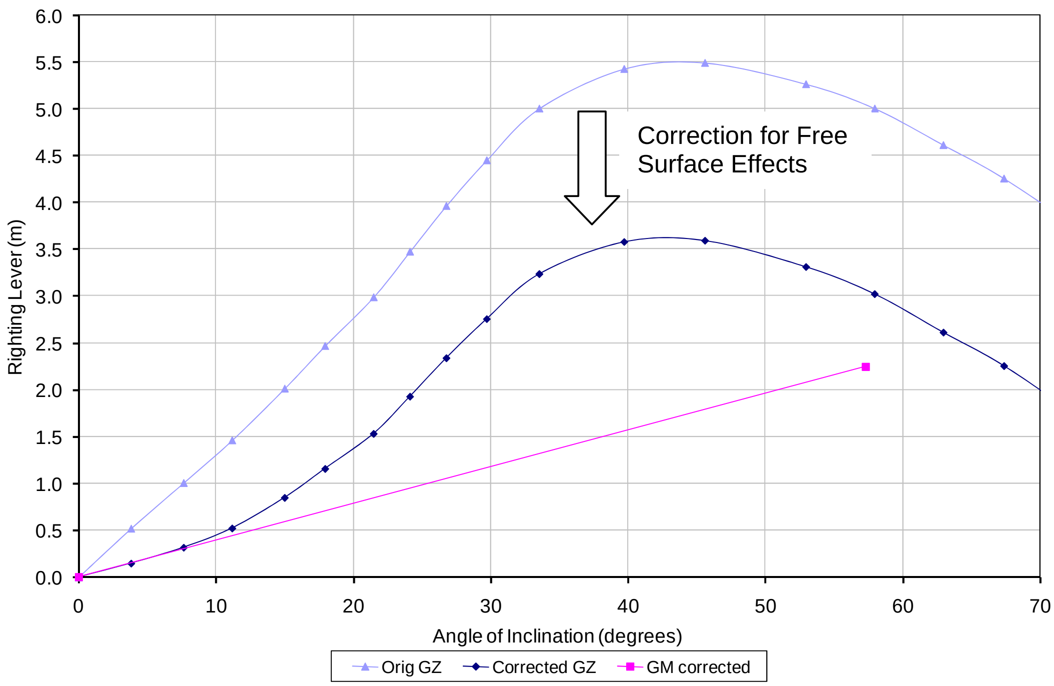


Figure 21: GZ Curve with Free Surface Correction

Influence of the Cargo Shift on Stability

The progressive shift of the cargo to one side of the hold imparts a horizontal and vertical shift in the laden ship's centre of gravity (CoG).

For the case of the ship listed at 22 degrees, the GZ curve corrected for free surface effects is adjusted to account for the cargo shift as follows (further details can be found in Appendix B):

1. It is assumed that to incline the vessel to a steady angle of heel of 22 degrees, the surface profile of the cargo has shifted through an angle ϕ. This involves the shift of a wedge shaped portion of cargo from one side of the vessel to the other (see Appendix B).

2. The horizontal shift in the iron sand centre of gravity reduces the GZ curve by

   $$(W\ h_1 / \Delta) \cos\theta$$

   where
   W = weight of shifted cargo
   h_1 horizontal shift in the shifted cargo mass
   Δ = displacement of ship
   θ = angle of inclination

3. The vertical shift in the cargo centre of gravity reduces the GZ curve by

   $$(W\ h_2 / \Delta) \sin\theta$$

   where h_2 = vertical shift in the shifted cargo mass.

4. The shift in the cargo centre of gravity reduces the GM by Wh_2/Δ, from 2.2m to 2.1m.

The adjustment to the GZ curve from the horizontal and vertical shift in the cargo centre of gravity is shown in Figure 22. Two curves are shown in this figure:

1. The GZ curve corrected only for free surface effects
2. The final GZ curve adjusted for free surface effects and cargo shift

Figure 22 shows two points of intersection of the GZ curve adjusted for free surface effects and cargo shift with the x-axis. The first point of intersection is the steady angle of heel the ship takes up due to the cargo shift. The second intersection occurs at the angle of vanishing stability – for angles of inclination less than this, the ship will return to its upright condition when the heeling moment is removed. Note that in this instance, down flooding would occur prior to this angle of inclination being achieved.

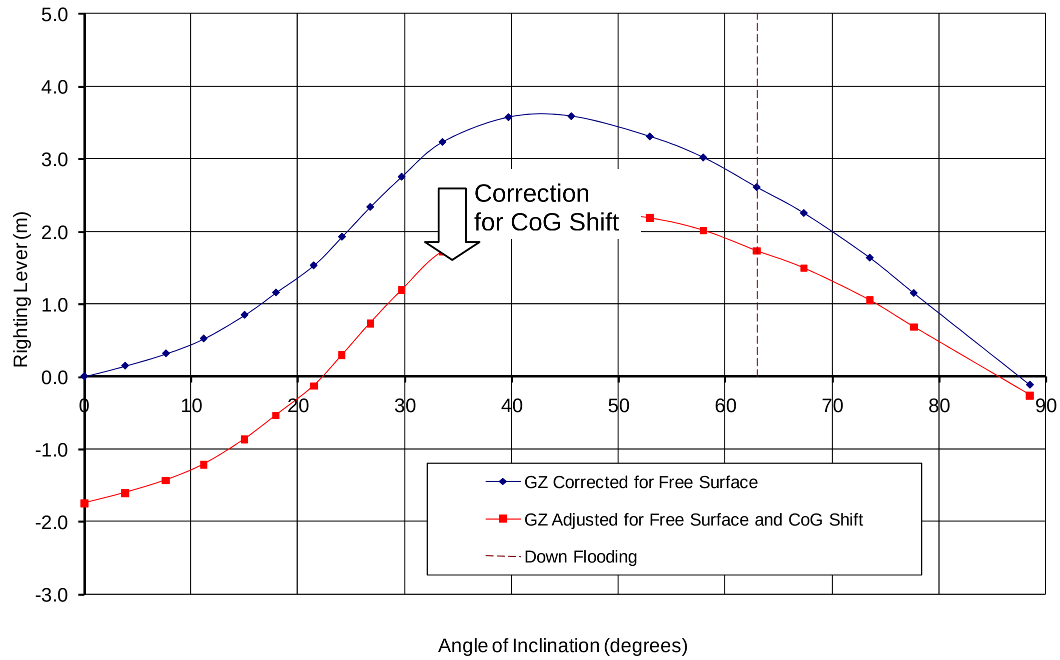


Figure 22: GZ Curve with Adjustment for Cargo Shift

The adjusted GZ curve is re-plotted in Figure 23, with the first point of intersection (i.e. the steady angle of heel) as the origin of the graph. The x-axis in this graph is the angle of inclination from the 22 degree steady angle of heel position.

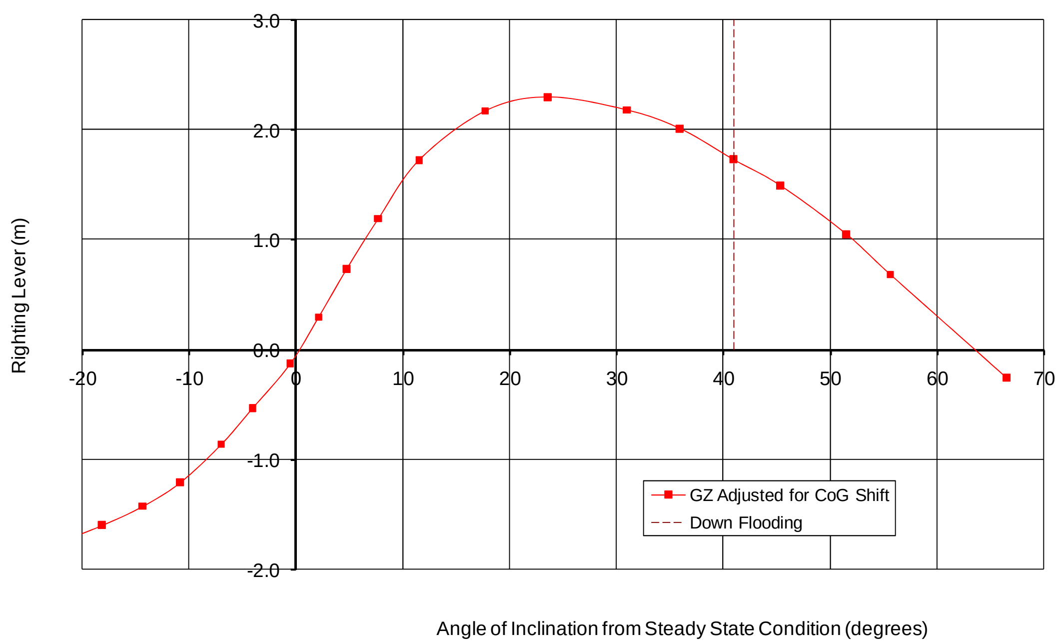


Figure 23: Adjusted GZ Curve about Steady State Heel Angle

Stability Criteria

Table 3 compares the main features of the ship's stability for the original condition (as given by the loading computer) and the adjusted condition including free surface and cargo shift. The intact stability criteria according to IMO Res. A.167 (as referenced in the ship's loading manual [8]) are listed for comparison.

Criteria	Original Condition	Free Surface & Cargo Shift Condition	% Reduction	IMO Stability Criteria
GM	7.27 m	2.1 m	71%	0.15 m
GZ Max	5.53 m	2.3 m	58%	0.2 m
Angle of GZ Max	44 deg	23 deg	48%	30 deg [1]
Area under GZ curve up to 30 degrees	1.088 m-rad	0.87 m-rad	20%	0.055 m-rad
Area under GZ curve up to 40 degrees (or down flooding angle if less)	1.969 m-rad	1.22 m-rad	38%	0.09 m-rad
Area between 30 deg and 40 deg (or down flooding angle if less)	0.881 m-rad	0.35 m-rad	60%	0.03 m-rad

Notes:
[1] The maximum righting arm should occur at an angle of heel preferably in excess of 30 deg but not less than 25 deg.

Table 4: Intact Stability Summary

Stability Assessment for Effects of Wind and Rolling

The ability of the ship to withstand the combined effects of heeling due to beam winds and rolling has been investigated for an angle of inclination of 22 degrees. The approach used is detailed in the ship's loading manual [8] which references the Intact Stability Criteria of IMO resolution A.562(14). The adjusted GZ curve and the severe wind and rolling criterion are presented in Figure 24, with areas A and B determined as follows:

Effect of wind
The ship is considered to be subject to a steady wind pressure acting perpendicular to the ship's centreline, resulting in a steady wind heeling lever (lw1). The calculations identified the wind heeling lever to be negligible (<0.03).

Comparison with the ship's loading computer calculation of wind heeling lever for the applicable load case highlighted an error in the data used by the loading computer for this calculation (contained in the file "IMO562.DAT"). An investigation discovered that the data for the parameter Z (the vertical distance from the centreline of the projected lateral area of the ship above the waterline to the centre of the underwater lateral area) was incorrect. This results in the loading computer greatly over predicting the wind heeling lever by a factor of approximately 20.

Action of the waves in rolling the ship
From the equilibrium position (intersection of the GZ curve and the wind heeling lever curve lw1) the ship is assumed to roll to windward owing to wave action. The angle of roll to windward ($\theta 1$) due to the action of waves is calculated to be 12.5 degrees using the methods of IMO Res. A562(14).

The ship is then subjected to a gust wind pressure which results in a gust wind heeling lever lw2.

The area A corresponds to the energy imparted to the ship by the wave induced roll to windward. This will exist as kinetic energy when the ship rolls back through the equilibrium position (with some reduction of energy due to water resistance). The energy carries the ship past the equilibrium position and must be absorbed by the water as the ship rolls to leeward. There must be sufficient capacity in area B to absorb this energy (i.e. Area B > Area A), or the ship will capsize.

Stability Criteria
The area B (taken up to the angle of down flooding or 50 degrees, whichever is less) is required by the IMO stability criteria to be greater than or equal to area A. In this case the area has been taken up to an angle of 50 degrees from the upright condition.

Area A	10 m deg
Area B	45 m deg
Area B / Area A	4.5

Table 5: Beam Winds & Rolling Intact Stability Criteria

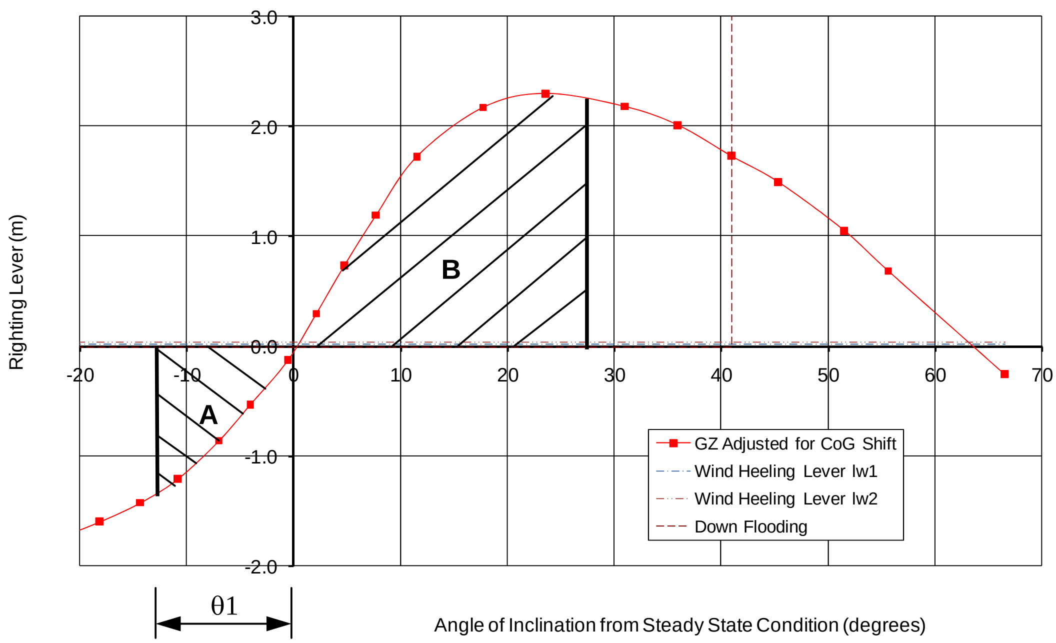


Figure 24: Adjusted GZ Curve about Steady State Heel Angle

Slurry Stability

The iron sand angle of repose (Coulomb angle) of 50 deg [9] is well within the maximum reported list of 22 deg. However, the free water sloshing can result in the movement of the iron sand. This can be caused by either:

1. the flow of water over the sand, and
2. the pressure gradient due to the non-uniform water height.

Both of these are investigated using fundamental multiphase theory. Ref [9] finds that if the ratio of the separation velocity w_P and the typical velocity w_T is much less than 1 (i.e. $W_P / W_T << 1$), particles are mixed in a fluid flow. In the current flow, this ratio is found to be approximately 0.02, compared to the threshold for mixing of 0.2 [10]. This indicates that iron sand will be entrained in the water due to the fluid motion. The second mechanism inducing sand motion is the pressure gradient. The comparison the Coulomb friction force (which resists motion) to the applied pressure gradient (which displaces the sand) shows that the global pressure gradient is not large enough to cause the movement of the iron sand (Figure 25). However, local pressure gradients due to sloshing impacts are far greater and may result in the displacement of the iron sand (Figure 26).

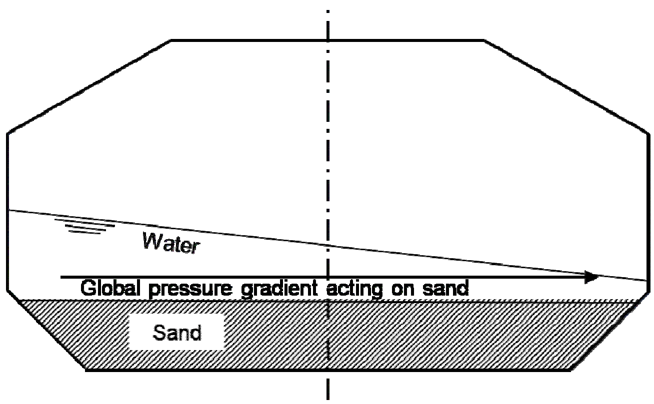


Figure 25: Global Pressure Gradient Acting on Sand

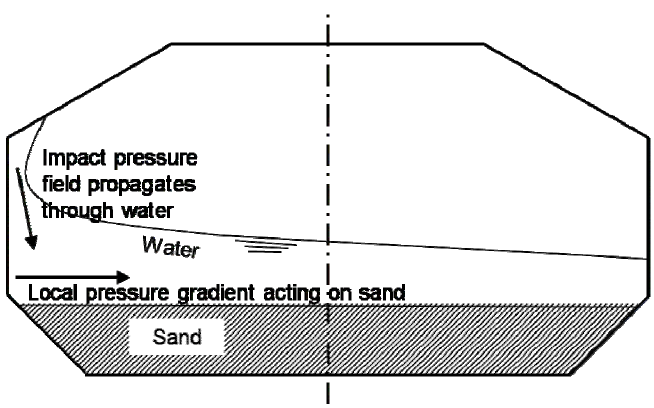


Figure 26: Global Pressure Gradient Acting on Sand

Assessment of Ship’s Stability with Free Surface and Cargo Shift

The assessment of the ship’s stability with free surface and cargo shift shows a considerable reduction in the stability parameters when compared to the original condition given by the loading computer. However, in general the IMO stability criteria of Res A.167 are passed (see Table 4). The exception is the angle of maximum GZ. This occurs at angle of 45 degrees to the upright - whilst acceptable in the upright condition, the 22 degree steady heel reduces this angle below the minimum acceptable 25 degrees.

At the observed heel angle of 22 degrees the comparison of areas A and B shows a good reserve of stability. (Area B / Area A = 4.5). However, the rate of cargo shift is likely to increase as the heel angle increases, leading to further degradation in the vessel’s stability over time. It is estimated that this criterion would be failed when the cargo shift resulted in a steady heel angle of approximately 32 degrees.

It is worthwhile to draw comparison between the cargo shift on the “Taharoa Express” and the requirements for vessels carrying grain in bulk. Grain cargoes are prone to shifting and so specific stability criteria have been developed to take account of the heeling moments due to grain shift (International Code for the Safe Carriage of Grain in Bulk). These requirements state that the angle of heel due to grain shift shall not exceed 12 degrees. This angle of heel was considerably exceeded on the “Taharoa Express” due to the cargo shift.

It is our opinion that whilst the “Taharao Express” had a good reserve of stability at the 22 degree heel angle, if the cargo continued to shift this reserve would be eroded leading to the eventual capsize of the vessel if left unchecked.

References

1. Analyses, Coastal Marine Forecasts (Raglan and Stephens) for the Period 17 to 22 June 2007, Metservice, 23 August 2007
2. “Voyage 65 Extended Trend.xls”, Taharoa Wave Rider Buoy Data, 18 to 22 June 2007.
3. Abramson, HN. The dynamic behaviour of liquids in moving containers. Report NSP-106, National Aeronautics and Space Administration, 1966.
4. Ibrahim, RA. Liquid Sloshing Dynamics. Cambridge University Press, 2005.
5. Rizzuto, E. and Tedeschi, R. Surveys of actual sloshing loads onboard of ships at sea. NAV 97: International Conference on Ship and Marine Research, pp 7.29–7.37, 1997.
6. Lloyds Register. Comparative sloshing analysis of LNG ship containment systems, 2005.
7. Rawson, KJ. and Tupper, EC. Basic Ship Theory, 4th ed. Longman Group, 1994.
8. “Trim Stability and Longitudinal Strength Calculation – 137,900 dwt Slurry Carrier - Taharoa Express”, NKK Corporation, 15/4/99
9. “Bluescope Steel - Iron Sand Sample”, CCI Ref. No. N8156, CCI Australia Pty Ltd, 22/08/07
10. Brennen, C. Fundamentals of Multiphase Flow. Cambridge University Press, 2005.
11. NKK, Load on Bulkhead at Slurry Loading, Doc. No. H-04110, April 30 1998.
12. “TMR4205 Buckling and Ultimate Strength of Marine Structures”, Professor Jørgen Amdahl, NTNU Department of Marine Technology.

.

Appendix A

Sloshing Assessment

LR Fluids Meshes

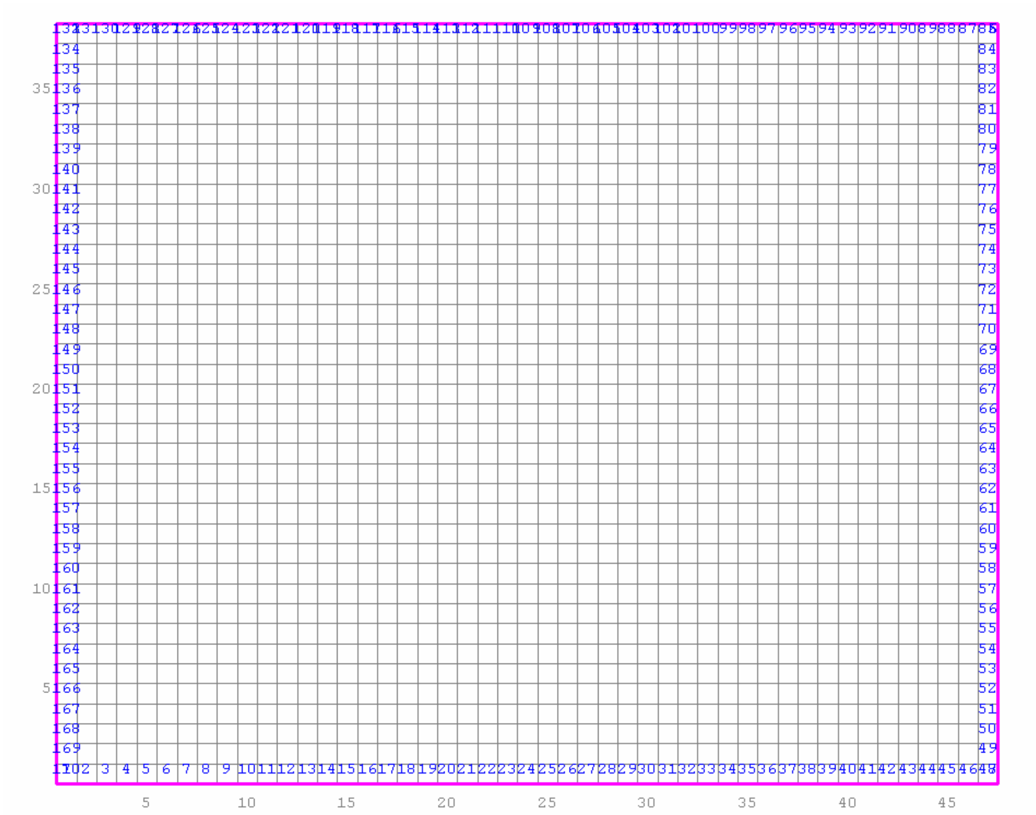


Figure A1: Mesh for Longitudinal Cross-Section of Cargo Hold No.5

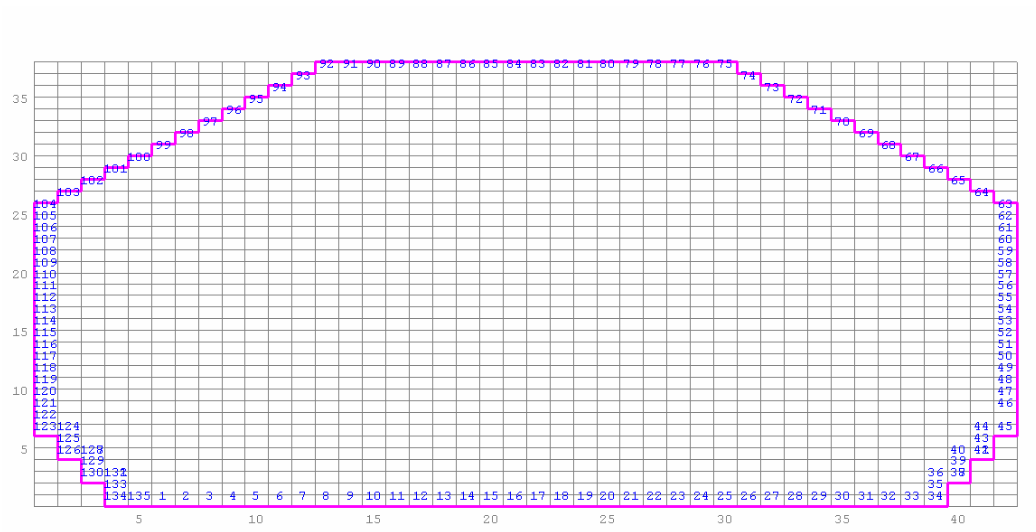


Figure A2: Mesh for Transverse Cross-Section of Cargo Hold No.5

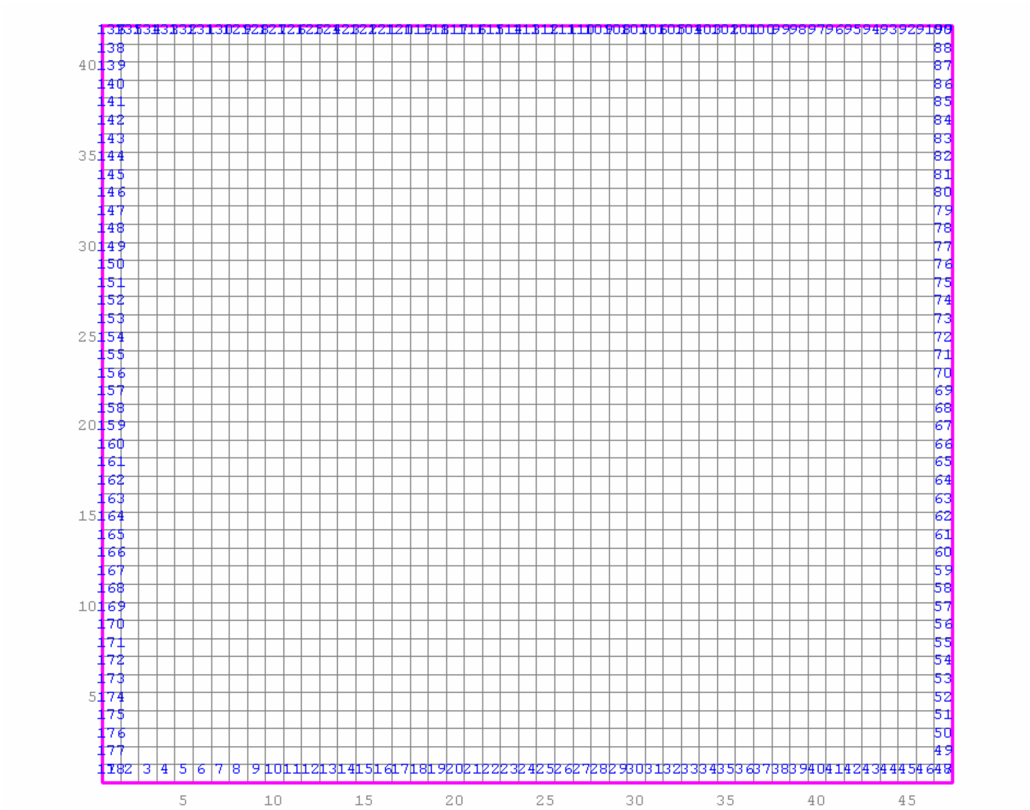


Figure A3: Mesh for Longitudinal Cross-Section of Ballast Hold No.6

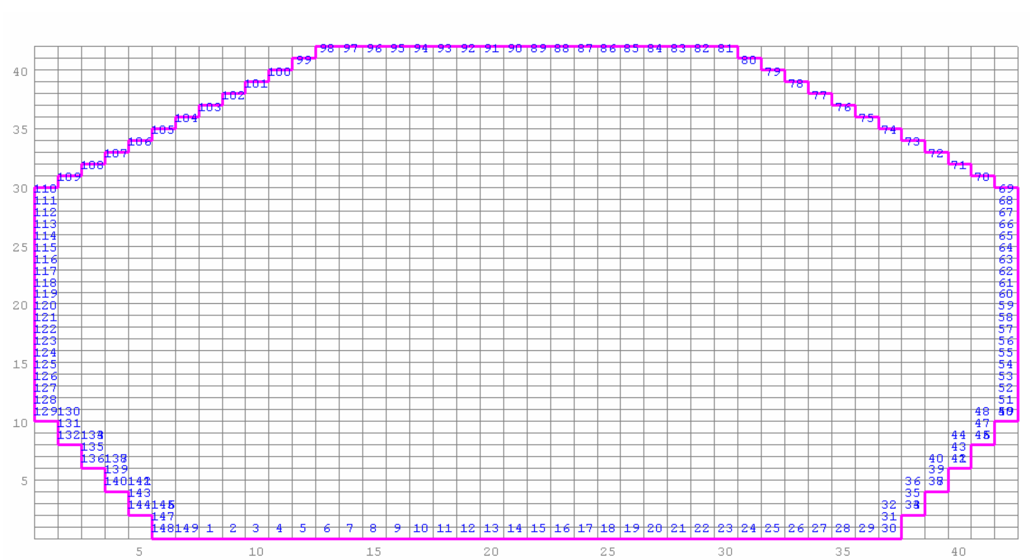


Figure A4: Mesh for Transverse Cross-Section of Ballast Hold No.6

Computational Models

Parameter	Computational model
Discretisation	Finite difference
Free surface	Marker-and-cell (interface tracking)
Grid spacing	Transverse cross section: 1 m horizontal, 0.5 m vertical
	Longitudinal cross section: 0.5 m horizontal, 0.5 m vertical
Time step	Adaptive (using local Courant number limit of 0.2)
Pressure-velocity coupling	Staggered grid
Sloshing implementation	Body force
Sloshing motion	Sinusoidal
Density	1,025 kg/m^3
Viscosity	10^{-6} m^2/s
Compressibility	Slightly compressible

Table A1: Computational Models used in LR Fluids

Appendix B

Methodology for Cargo Shift Stability Correction

To determine the correction to the GZ curve due to the shift in the cargo, the methodology presented in this Appendix has been used.

It is assumed that to incline the vessel to a steady angle of heel of 22 degrees, the surface profile of the cargo has shifted through an angle ϕ. This results in the shift of a wedge shaped portion of cargo from one side of the vessel to the other, as shown in Figure B1. The correction to the GZ curve comprises components due to the horizontal and vertical shift in the cargo mass moved.

In order to calculate the cargo shifted CoG for the ship, the vertical shift in the cargo mass (h_2) is required.

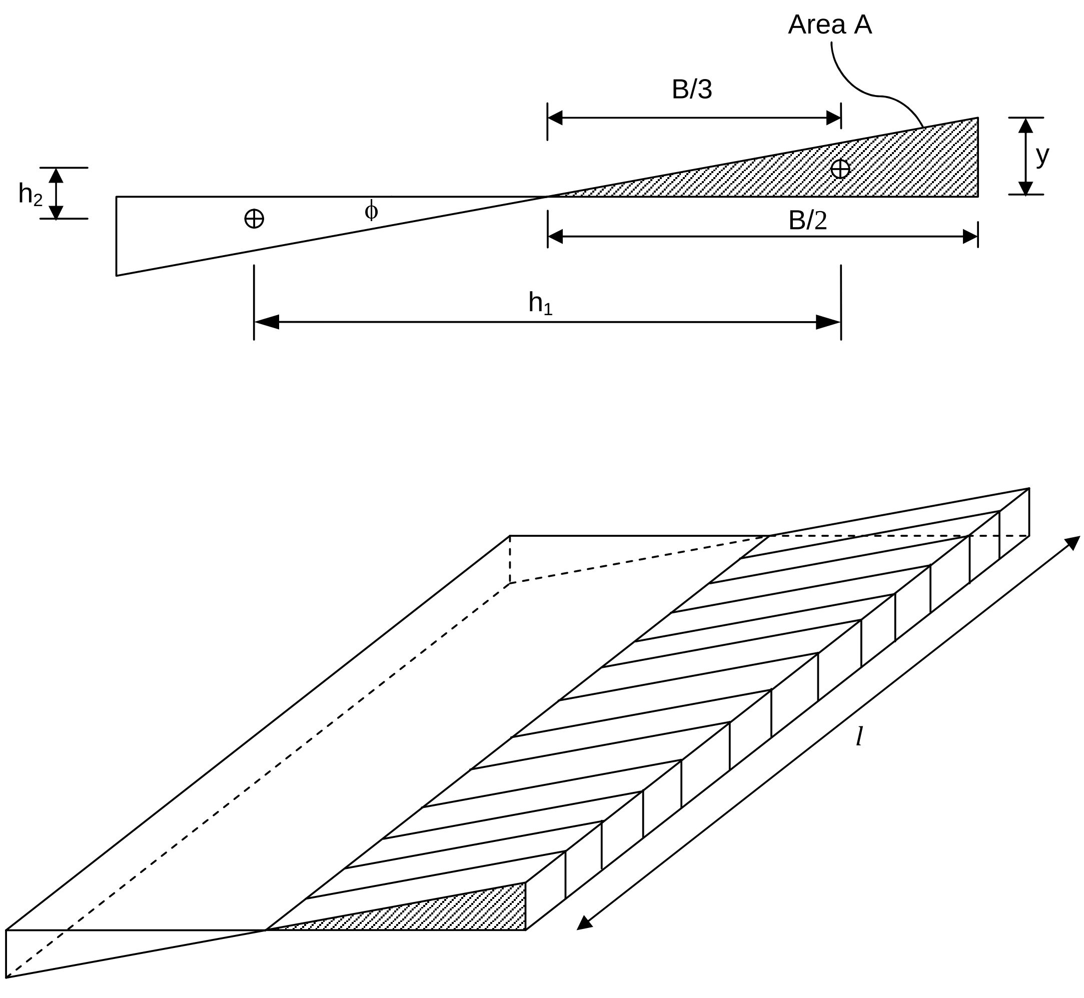


Figure B1: Cargo Shift

h_1 = horizontal shift in the shifted cargo mass

h_2 = vertical shift in the shifted cargo mass

δ_{IS} = density of iron sand

B = cargo hold breadth

l = total length of cargo holds

$$h_1 = 2 \times \frac{2}{3}\left(\frac{1}{2}B\right) = \frac{2}{3}B$$

$$h_2 = \frac{2}{3}y$$

$$y = \frac{3}{2}h_2$$

Weight of shifted cargo mass:

$$W = \frac{y \cdot l \cdot B \cdot \delta_{IS}}{4}$$

$$W = \frac{3 \cdot h_2 \cdot l \cdot B^2 \cdot \delta_{IS}}{2 \cdot 4} = \frac{3 \cdot h_2 \cdot l \cdot B \cdot \delta_{IS}}{8}$$

The new corrected GZ values, G_1Z_1, after the cargo shift are calculated by:

$$G_1Z_1 = GZ_{free} - X\cos\theta - Y\sin\theta$$

Where GZ_{free} = free surface corrected values of GZ

$$X = \frac{Wh_1}{\Delta} = \frac{W \cdot 2 \cdot B}{3 \cdot \Delta} = \frac{6 \cdot h_2 \cdot l \cdot B^2 \cdot \delta_{IS}}{24 \cdot \Delta} = \frac{h_2 \cdot l \cdot B^2 \cdot \delta_{IS}}{4 \cdot \Delta}$$

$$Y = \frac{Wh_2}{\Delta} = \frac{3 \cdot h_2^2 \cdot l \cdot B \cdot \delta_{IS}}{8 \cdot \Delta}$$

For the case of the ship inclined to a steady angle of heel of 22 degrees, $\theta = 22°$ and $G_1Z_1 = 0$

$$0 = GZ_{(free\,surface@corr.\,at\,22°)} - \frac{h_2 \cdot l \cdot B^2 \cdot \delta_{IS}}{4 \cdot \Delta}\cos\theta - \frac{3 \cdot h_2^2 \cdot l \cdot B \cdot \delta_{IS}}{8 \cdot \Delta}\sin\theta$$

Solving this second order equation for h_2:

$$\boldsymbol{h_2} = \frac{-4 \cdot \boldsymbol{\Delta}}{3 \cdot l \cdot B \cdot \delta_{IS} \cdot \sin\theta} \cdot \left(\frac{l \cdot B^2 \cdot \delta \cdot \cos\theta}{4 \cdot \boldsymbol{\Delta}} \mp \sqrt{l}\sqrt{B}\sqrt{\delta} \frac{\sqrt{l \cdot B^3 \cdot \delta \cdot \cos\theta^2 + 24 \sin\theta \cdot GZ_{22} \cdot \boldsymbol{\Delta}}}{4 \cdot \boldsymbol{\Delta}} \right)$$

The above methodology requires two simplifying assumptions:

1. The cargo profiles observed by the crew suggested that the shifted cargo had a more ‘humped’ profile rather than the flat, inclined surface assumed by the above method;

2. The method presented assumes a wall sided hold, but the presence of the lower hopper will affect the cargo shift areas;

However, calculation of the cargo shift stability correction using the crew estimated cargo profiles gives similar results, confirming the validity of the above approach.

Appendix C

Slurry Stability Calculations

Taharoa Express - Iron Sand Entrainment

This calculation assesses whether iron sand is entrained in the sloshing flow due to
(1) pressure gradients and
(2) fluid velocity.

The calculations are performed according to procedures in 'Fundamentals of Multiphase Flows' by C Brennen.

Parameters

Critical Angle	$\phi := 40 \cdot deg$
Approximate volume fraction of solid	$\alpha := 0.4$
Density of saturated iron sand	$\rho_s := 3153 \cdot \frac{kg}{m^3}$
Density of water	$\rho_1 := 1000 \cdot \frac{kg}{m^3}$
Water elevation at tank sides	$h_1 := 5 \cdot m$
	$h_2 := 21 \cdot m$
Kinematic viscosity of water	$\nu_c := 10^{-6} \frac{m^2}{s}$
Iron sand particle radius	$Ra := 0.1 \cdot mm$
Tank width	$beam := 42.5 \cdot m$
Particle drag coefficient (assuming spherical shape)	$C_D := 0.22$

Intermediate Calculations

Coulomb friction $\mu := \tan(\phi)$

Water height difference $\text{height} := h_2 - h_1$

Friction force $\Delta p := \mu \cdot \alpha \cdot g \cdot (\rho_s - \rho_1)$

Pressure gradient force $\text{dpdx} := \dfrac{\rho_1 \cdot g \cdot (h_2 - h_1)}{\text{beam}}$

Separation velocity $W_p := \left(\dfrac{2}{3} \cdot \dfrac{Ra \cdot g}{C_D} \cdot \dfrac{\rho_s - \rho_1}{\rho_1}\right)^{\frac{1}{2}}$

Typical velocity $W_t := \sqrt{\dfrac{\text{height}}{4 \cdot \rho_1} \cdot \text{dpdx}}$

Results: Pressure Gradient Ratio

$\dfrac{\text{dpdx}}{\Delta p} = 0.521$

Sand motion commences if >1,
no effect of pressure gradient if <1
Limit is 1.0

Results 2: Mixing Velocity Ratio

$\dfrac{W_p}{W_t} = 0.021$

Particles are separated if >>1,
mixed if <<1
Limit is approximately 0.2

Recent Marine Occurrence Reports published by
the Transport Accident Investigation Commission
(most recent at top of list)

08-201	Fishing charter vessel, *Pursuit*, grounding, Murimotu Island, North Cape (Otou), 13 April 2008
06-207	restricted limit passenger vessel, *Milford Sovereign*, engine failure and impact with rock wall, Milford Sound, 31 October 2006
06-204	fishing vessel "Kotuku", capsized, Foveaux Strait, 13 May 2006
07-201	charter catamaran, *Cruise Cat*, collision with navigational mark, Waikato River entrance, Lake Taupo, 22 February 2007
06-208	fishing vessel *Santa Maria II*, engine room fire, L'Esperance Rock, Kermadec Islands, 10 December 2006
05-212 Incorporating	restricted limit passenger vessel *Milford Sovereign*, loss of directional control, Milford Sound, 20 November 2005 incorporating:
06-206	restricted limit passenger vessel *Fiordland Navigator*, heel due extreme wind gust in Milford Sound, 8 July 2006
06-201	passenger freight ferry *Aratere*, Heavy weather incident resulting in cargo shift, Cook Strait, 3 March 2006
06-205	fishing vessel, *Lady Luck*, collision and subsequent foundering, Motiti Island, Bay of Plenty, 23 June 2006
06-203	fishing vessel *Venture*, grounding, Tipi Bay, Tory Channel, 19 April 2006
05-211	container ship *Spirit of Resolution*, collision with bridge, Onehunga, 8 October 2005
05-210	restricted limit passenger vessel *Milford Mariner*, engines' stall resulting in grounding, Harrison Cove, Milford Sound, 18 September 2005
05-208	passenger freight ferry *Santa Regina*, near grounding, Tory Channel eastern entrance, 9 June 2005
05-207	freight and passenger ferry *Santa Regina* and private launch *Timeless*, collision, off Picton Point, Queen Charlotte Sound, 2 May 2005
05-206	passenger/freight ferry *Arahura*, loss of propulsion, Cook Strait, 24 April 2005
05-205	restricted limit passenger vessel *Black Cat*, control cable failure and collision with rock wall Seal Bay, Akaroa Harbour, 17 April 2005

Price $51.00 ISSN 0112-6962