ATSB
Australian Transport Safety Bureau

AUSTRALIAN TRANSPORT SAFETY BUREAU

MARINE SAFETY INVESTIGATION

REPORT 166

Independent investigation into the grounding
of the British flag passenger ship

# Regal Princess

in the Cairns harbour channel, Queensland
on 16 March 2001

COMMONWEALTH DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES


**Department of Transport and Regional Services**
**Australian Transport Safety Bureau**

# Navigation Act 1912
# Navigation (Marine Casualty) Regulations
# investigation into the grounding
# of the British flag passenger ship
# *Regal Princess*
# in the Cairns harbour channel
# on 16th March 2001

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**FIGURE 1:**
***Regal Princess***

# Incident summary

The British flag passenger ship *Regal Princess* arrived off the Queensland port of Cairns at about 0530 on 15 March 2001 and embarked a pilot to conduct the vessel for the inward passage. The weather was clear with a wind from the south-east at 15 to 20 knots at the pilot boarding ground.

Some difficulties were experienced with the handling of the vessel during the inward pilotage due to the windage of the ship and its manoeuvring characteristics. The ship swung in the turning basin and made fast port-side-to its assigned berth at about 0645. There was some minor damage sustained by the harbour tug through contact with *Regal Princess* during the berthing operation.

Sailing time was set as 1700 the same day.

At 1500 that day, a meeting was convened between the harbour master, the pilot, duty pilot, the ship's agent and the master of *Regal Princess* to discuss the departure. The pilot who conducted the inward pilotage was also assigned for the outward pilotage. He was concerned about both the height and ebb of the tide at the scheduled departure time of 1700. Together with a strong wind warning, these would combine to increase the difficulties in handling the ship.

The outcome of the meeting was that the sailing time was amended from 1700 to 0200 the next morning, 16 March 2001. At that time the wind was expected to have abated, the tide would be flooding and there would be a greater underkeel clearance (UKC).

At 0200 the vessel left her berth and proceeded outward. The wind was still from the south-east, at about 8 knots at the berth, increasing to 15 knots outside. The departure proceeded as expected until the ship reached the vicinity of beacon C14, when a series of pronounced yaws developed, culminating in the vessel grounding and coming to a stop at 0240 on the eastern side of the channel, with its starboard shoulder between beacons C14 and C12. The ship was aground for about 4 minutes. The ship was then manoeuvred off the bank and proceeded out to the anchorage.

Nobody was hurt as a result of the grounding and there was no pollution. The ship was checked internally for damage and found to be sound and seaworthy. As the sea state and current in Cairns prevented an inspection by divers at that time, the ship was released to proceed onward to Darwin. The underwater inspection in Darwin, the next port, revealed minor hull damage with a small area of the bottom plating having been set up under the bulbous bow, which was likely to be partly the result of an earlier grounding in the Carribean.

# Sources of Information

Master and officers of *Regal Princess*

Princess Cruise Lines, Los Angeles, and previous employees of Princess Cruise Lines

Queensland Transport – Regional Harbour Master

Pilot and Assistant Pilot for the Port of Cairns

Barrier Reef Pilot

Beaufort Shipping, Cairns

Holland America Line

Crystal Cruises

Mitsui OSK Lines


## Acknowledgment

The Inspector is grateful to Teresa Hatch, Naval Architect, for her advice and comments.

The Inspector is also grateful to Interdynamics Pty Ltd (www.interdynamics.com) for the computer program, FAID 330E, which was used in the analysis of fatigue factors.

The Inspector acknowledges the help and assistance of the Marine Accident Investigation Branch of the United Kingdom's Department for Transport and Broadgate Ltd, UK, in reading and supplying relevant data from the Voyage Data Recorder.

# *Regal Princess*

*Regal Princess* is a British flag passenger vessel operated by Princess Cruise Lines of Los Angeles, USA. The ship was on a cruise schedule arriving in the first Australian port, Hobart, from New Zealand then calling at Melbourne, Sydney, Cid Harbour, Cairns and continuing to Darwin and Singapore.

The vessel was built by Fincantieri at their Monfalcone yard in Italy in 1991. It is classed ✠100A1 by Registro Italiano Navale (RINA) and is measured at 70 285 gross tonnage.

*Regal Princess* is 245.06 m in length overall and has a moulded beam of 32.25 m. The bridge wings extend 1¼ m beyond the beam. The distance from the bridge wing to the bow is 45.89 metres and from bridge wing to stern is 199.17 m. The height from the waterline to the bridge is about 28.5 metres. The vessel has a salt water displacement of 36 575 tonnes at a draught of 8.1 m.

*Regal Princess* is a twin-screw diesel-electric powered ship. Electrical power is generated by 4 MAN-B&W 8L 58/64 8-cylinder medium speed engines producing a total of 37 640 kW. These engines provide the power for the two 12 000 kW electric propulsion motors. Each electric motor drives a single, fixed-pitch, six-bladed, 5 metre diameter propeller. This gives the vessel a normal cruising speed of 20 knots. The ship also has two tunnel bow thrusters (1 780 kW total) and two tunnel stern thrusters (2 575 kW total). The stern thrusters were a retro-fit. The ship has one semi-balanced rudder, situated on the centre line.

*Regal Princess* is equipped with an extensive range of bridge and navigation equipment including 4 ARPA radars (2 Racal Decca BridgeMaster and 2 Kelvin Hughes 6000). It has a Transas Electronic Charting and Display Information System and Magnavox, Trimble and Leica DGPS (Differential Global Positioning System) systems. The bridge has full bridge control of propulsion motors and thrusters. Also fitted are a Broadgate model 2000 Voyage Data Recorder and a ship simulator. The ship simulator is capable of simulating the ship's handling characteristics in various situations, ports and weather conditions.

During manoeuvring operations, the ship's bridge team consists of the master, staff captain, Officer of the Watch (OOW), Junior OOW and a helmsman. At the date of the incident all the ship's officers were Italian nationals. All were appropriately qualified.

*Regal Princess* has a comprehensive quality assurance system in place.

## Cairns harbour and approaches

The main shipping berths in the port of Cairns lie on the western side of Trinity Inlet adjacent to the city. Off the wharves, there is a turning basin 360 m in diameter with a depth of 7.0 m (380 m diameter at draughts of 6.3 m) at lowest astronomical tide. Access between the sea and the port is by a channel 5.7 miles in length, 90 metres wide (180 metres between each pair of beacons) and with a charted depth of 8.5 m below a chart datum based on Indian Springs Low Water. Queensland Transport, however, declares depths based on Lowest Astronomical Tide (LAT) datum, which is 0.2 m lower than chart datum. Depths referred to in this report will be referenced against a channel depth of 8.3 m based on LAT datum.

The channel consists of two legs; the first, outward from the berths and to beacon C20, is aligned 013° (T); the second, from beacon C20 to beacons C1 and C2 is aligned 029¼° (T). Shallow mud banks continue outward from the shore beside the channel to the vicinity of beacon C18 and the waters surrounding the channel progressively deepen from that point outward. Beacon C18 is also considered the most critical point of the channel – the banks

are closest to the dredged channel at this point. This outer leg has a sectored port entry light, providing a lead to the end of the channel. The inner section of the channel bottom to beacons C15 and 16 is mud, while from this point outward to beacons C1 and C2 it is sand.

The depth of the channel is regularly monitored and dredged if required by the Cairns Port Authority and any variations in the declared depth are promulgated by the regional harbour master. The charted minimum depth of the Cairns port approach channel is 8.3 m below LAT. The channel is subject, over time, to a reduction in depths through channel silting and bank collapse. A Queensland temporary marine notice, 086(T) of 2001 was issued based on information as of 19 January 2001 noting a least depth of 7.9 m. No Australian chart corrections, however, had been promulgated to amend the 8.3 m.

Cairns harbour pilot boarding ground is located at 16°48.6'S 145° 50.6'E .

## Port administration

Cairns Port Authority is a government corporation charged with overseeing the management and operation of Cairns airport and the sea port, including both commercial activities and the maintenance of the port infrastructure.

In 1996, the Maritime Division of the Queensland Department of Transport undertook a full-scale measurement of the effects of squat[1]. The vessel used in the trial was the twin screw/twin rudder cruise liner *Crystal Symphony*. *Crystal Symphony* has a length overall of 238 m, a length between perpendiculars of 203 m and a beam of 32.8 m. The trial, both inwards and outwards, was conducted at draughts of between 7.43 m and 7.3 m. At about 12 knots, the maximum sinkage (squat) experienced was 0.6 m, less than that indicated by the ship's squat tables.

Cairns is the second busiest cruise port in Australia. In 1999, international cruise ships made 31 calls to the port. The largest passenger ship to visit the port before the incident was *Legend of the Seas* at 264.26 metres LOA, which berthed at Cairns in December 1999.

Queensland Transport's regional harbour master is based in Cairns. The harbour master is responsible for the safe and proper control of ships in the pilotage area.

The pilotage services for the port are provided by Ports Pilots Queensland Pty Ltd, a subsidiary of Ports Corporation Queensland.

## Vessel approval system

The port operations manual specifies limiting criteria for non-passenger vessels using the port. The maximum criteria for routine port visits are set as follows:

- length overall 200 m;
- maximum beam 32 m;
- for vessels over 40 000 gross tonnes, minimum channel UKC is 2.0 m;
- minimum UKC in turning basin is 0.6 m;
- speed limit seaward of beacon 9, 10 knots;
- speed limit inshore of beacon 9, 8 knots.

Passenger ships typically have a flared bow and a raked stem so, while the length overall may be significantly in excess of the 200 m length limit, the length on the water line is often only marginally in excess of the length limit. Before any passenger vessel over 200 m in length can visit the port of Cairns, the operators of the vessel make a written application to enter the port. Critical to the assessment is the ship's draught, windage and its underwater profile in the channel.

[1] Squat, the supplementary sinkage of the ship, relative to the undisturbed water level, which is caused by movement of the ship at a given speed.

The application is also forwarded to the Duty Pilot (of Ports Pilots Queensland) for assessment against the ship's particulars, the predicted tidal conditions, the ship's squat characteristics and any other relevant criteria. The pilots then advise the harbour master who reviews the assessment. If appropriate, the harbour master gives the final approval and acknowledgment, with any comments or conditions, to the shipping company through the local agents.

In May 1999 an initial approach was made to the harbour master regarding a proposed port visit by *Regal Princess*, the first to the port by this vessel. The original proposal was for a visit on 11 March 2001, which was later amended to 15 March 2001. There were several exchanges of information between the port and the company. An assessment was made of the ship's draft/beam ratio and channel blockage factor[2]. These two ratios were greater than for four smaller ships with which *Regal Princess* had been compared. In October 2000, it was noted that four smaller cruise ships had been subject to pronounced bank effect at a UKC of less than 1.5 m in the vicinity of beacon 18.

Considering the above criteria, the harbour master imposed four conditions based on the ship's sailing time and a maximum draught of 8.1 m. These were:

- departure before 1900 on 15 March;
- minimum UKC of 1.5 m to be maintained in the channel at all times;
- the vessel's speed not to exceed 12 knots in the channel;
- any increase in the draught above 8.1 m would require an earlier departure;

No mention was made of weather conditions.

In February 2001 the ship's agent advised that there was an increase in the maximum draught to 8.2 m. The amended date of 15 March 2001 was also proposed. On 6 March an amended approval was given for the ship to depart at 1700 on 15 March, subject to the ship's draught not exceeding 8.2 m.

Both the original and amended conditions for the vessel's entry to the port were sent by e-mail to the ship's agents, the Cairns Port Authority and the Cairns pilots.

## Pilot service

Ports Pilots Queensland Pty Ltd currently provides the pilot service for Cairns. This recently established company consists of fifteen marine pilots. These pilots were employed formerly by Queensland Transport under the regional harbour master. Eight of these pilots now provide pilotage services for Cairns as well as eight other North Queensland ports.

On a rotational basis, one of the pilots acts as 'Duty Pilot' for the week and this pilot then also provides the required clerical and organisational services for the company. One of these tasks is the assessment of passenger ships for entry approval and to provide advice to the harbour master for final review and approval.

Whilst the service does have a small office in Cairns, most of the duty pilot's work is done by phone, fax and e-mail from his/her own home. The necessary files and documents are handed over to the next duty pilot at the end of each rostered duty period. The large distances between the different ports serviced and the associated travelling times, together with the individual's duty cycle, mean that all aspects of communication between the various pilots is challenging.

2 Channel blockage factor is the ratio between the ship's midships cross sectional area and the cross sectional area of the channel.

# Narrative

On 11 March 2001, *Regal Princess* sailed from Sydney for Cairns with 1387 passengers and 700 crew on board. On 14 March 2001, on the way to Cairns, the vessel visited Cid Harbour in the Whitsunday Islands before arriving at Cairns the following day.

## Inward pilotage

At about 0530[3] on the morning of 15 March the ship embarked the Cairns harbour pilot, together with a trainee pilot, at the pilot boarding ground. The ship's arrival draught was 8.11 m forward and 8.10 m aft. At the boarding ground, the weather was generally good with clear visibility and a south-easterly wind of 15 to 20 knots. The tide was ebbing with a height above datum of 2.0 m, giving the vessel an underkeel clearance (UKC) of 1.8 m, based on the least depth at beacon 18, but with a general UKC of 2.4 m.

The inward pilotage commenced after the master and pilot had exchanged information about the passage to the berth, the ship's characteristics and after the pilot had made an assessment of the vessel's leeway. During this exchange, the master also expressed some concern about the wind strength.

At the time of boarding, the pilot was unaware of the fact that the ship was fitted with only a single rudder, of the speed restriction imposed and of certain other critical factors concerning the ship. He was given this information during the exchange with the master, when he was also informed of the configuration of the two bow thrusters and two stern thrusters, together with the fact that the ship did not steer well below a speed of ten knots. He was also advised that the effect of the thrusters diminished considerably at speeds above about 4 knots. The major significance of this is that the vessel has restricted handling characteristics, particularly steering response, through the speed range between 4 and 10 knots.

The master was reminded (he had been informed a couple of days earlier by e-mail) that the declared depth in the channel was, at the time, reduced to 7.9 m.

The pilot experienced difficulty in handling the vessel from the beginning of the inward passage. The ship's superstructure provided a large windage area and the ship made significant leeway, which the pilot assessed before entering the channel. During a reduction in speed on the inward passage, the ship took a large sheer to starboard and effectively lost steering. The situation was recovered with an increase in speed and use of the thrusters.

The inward passage proceeded without further incident until just prior to berthing, when the tug was caught by the effect of the ship's movement and the tide. The tug contacted the ship's starboard quarter causing slight damage to its mast light. After swinging in the basin, the ship berthed, port-side-to, at its assigned berth.

## Outward pilotage

The pilot who had conducted the inward passage was also scheduled to conduct the outward passage. The scheduled sailing time gave the pilot some concern in view of significant restrictions on the ship's manoeuvrability experienced on the inward passage at speeds between 4 knots and 10 knots. Sailing was due at 1700, there was a strong wind warning current for that afternoon and the tide would also be on the ebb with a predicted height above datum of 1.6 m, giving a UKC of 1.4 m.

In view of the pilot's concern, a meeting was called to discuss the projected sailing time. At

3 All times are Australian Eastern Standard Time

1500 on the afternoon of 15 March, the ship's master attended the meeting ashore with the harbour master, the pilot, duty pilot and the ships agent. At the meeting it was agreed to delay the sailing until 0200 the next morning as the wind was forecast to moderate and the tide would be flooding with a predicted height above datum of 2.0 m. Stemming the tide, together with a UKC of 1.8 m, would improve the ship's handling.

At 0200 the next morning, 16 March, the ship sailed on the flood tide with a height above datum of 1.9 m. The wind was from the south-east at 15 knots at the pilot boarding ground.

On the bridge at sailing and on passage through the entrance channel were the pilot, the master, the staff captain, the OOW and a helmsman. Observing, but playing no part in the bridge team were also the harbour master, a trainee pilot and the reef pilot. The ship sailed to a plan mutually agreed between the master and the pilot.

The master, as is common with passenger ships, undocked the vessel then, when the ship was safely on the first set of leads, he handed the 'con' to the pilot. The master then stationed himself to operate the engine telegraphs. The staff captain was at the bow and stern thruster controls. The ship's progress was being monitored on the electronic chart and the positions fixed by the OOW, using radar positions, on the paper chart.

The vessel proceeded by the plan, the bridge passing beacon C20 at 0221:30 and beacon C18 at 0227:15, at about 6.6 knots. This area was considered the critical point of the channel and the ship tended towards the starboard side of the channel. Between C18 and C16 the ship was constantly being set to the west (the port side of the channel). This was attributed to a wind, estimated by the master to be 25 knots, on the starboard beam. The pilot had to adjust course accordingly. As *Regal Princess* approached beacon C15, the pilot asked for the ship's speed to be increased to 10 knots. The bridge passed between beacons C15 and C16 at 0232. The ship was just to the port hand side of the channel on a heading of 30.6° (T) making good a course of 029° (T) with about 2° leeway.

## The grounding

At 0233, *Regal Princess* was still slightly to port of the centre line of the channel on a heading of 031° (T), making good a course of 029° (T) at a speed of 9.5 knots. At 0233:17 the ship was on the centre line of the channel, moving to starboard. At 0234 the ship's centre line was about 45 m to starboard of mid channel. The ship's heading changed to 034.7° (T) and the course made good 031° (T) at a speed of 9.6 knots.

One minute later, at 0235, the ship was in mid channel when the heading altered rapidly, nearly 14° to port, to a heading of 021° (T) and the course made good to 029°. The speed reduced slightly to 9.2 knots. At 0236 *Regal Princess* was to port of mid channel when the head altered rapidly to starboard to a heading of 035° and the speed dropped further to 8.9 knots. At about 0236:35 the ship's bow crossed the toe line. At 0237 the ship's head was on 040.7° (T) and the speed fell to 8 knots. The ship decelerated to a stop over a period of about 3 minutes.

At the time of grounding the wind direction and strength was variously described by witnesses as light with some gusts along the line of the valleys, to 25 knots south-easterly. The recorded wind direction and speed at Cairns Airport at 0235 was 150°(T) at a maximum of 9 knots.

## Refloating

The pilot engaged a tug to render assistance. This tug was following the ship out of the port on its way to a neighbouring port. Initially it was asked to come to the stern and take a line

but, before that could happen, it was decided to use it to push on the starboard bow. One of the concerns at the time was beacon C13, which was close astern on the other side of the channel. The combination of tug, engines and thrusters, however, was sufficient to free the vessel from the mud at the side of the channel and the ship was brought astern into the middle of the channel. Once clear of the bank, it continued ahead in the channel until finally clear when the pilot disembarked and the ship proceeded onwards to the anchorage.

A thorough internal inspection of the ship and its tanks found that the ship was safe and the hull sound. All the relevant ship's systems were tested and found to be still fully operational. The conditions of current and weather in Cairns at that time prevented an inspection by divers but, after appropriate inspections and release by Australian Maritime Safety Authority (AMSA), the ship continued on its voyage to Darwin.

When *Regal Princess* arrived in Darwin, an inspection by divers revealed a small amount of damage under the bulbous bow where there was some minor indentation of the shell plating although it was likely that this was partly the result of an earlier grounding in the Carribean.

# Comment and analysis

## Evidence

This report is based on interviews with the pilot, the master, staff captain, second mate and third mate of *Regal Princess*. Evidence was also obtained from the ship's voyage data recorder (VDR), the electronic chart system (ECDIS), DGPS, charts, logs, engine data recorder, course recorder and other bridge documents. The course recorder trace was determined to be 1½° high and about 1½ minutes slow of the GPS and the rudder angle recording pen was inoperative. The port engine telegraph recorder was not recording engine orders, although it was still recording changes in engine revolutions.

Further information was obtained from the trainee pilot, the Cairns regional harbour master and the Great Barrier Reef pilot, all of whom were on board at the time of the grounding, and also from the General Manager, Cairns Port Authority, and the ship's agent.

This was the first time *Regal Princess* had called at the port of Cairns. The master in command at the time, had not been to the port for about 20 years.

The ship presented as a well-run vessel with a comprehensive management system. All those systems and equipment critical to the operation of the ship were fully functional.

## The grounding

Contributing to the grounding was a combination of the following factors:

a) the blocking effect due to the sheer size of *Regal Princess* in relation to the cross sectional area of the channel;

b) the poor steering characteristics of a ship with twin screws and a single rudder;

c) bank effect[4] of the channel; and possibly

d) leeway due to the wind.

## Ship/channel factors

*Regal Princess* has an overall length of 245 m and a length of about 214 m at the waterline. Below the waterline the ship, from the fore end of the bulbous bow to the after end of the rudder, is about 216.5 m in length.

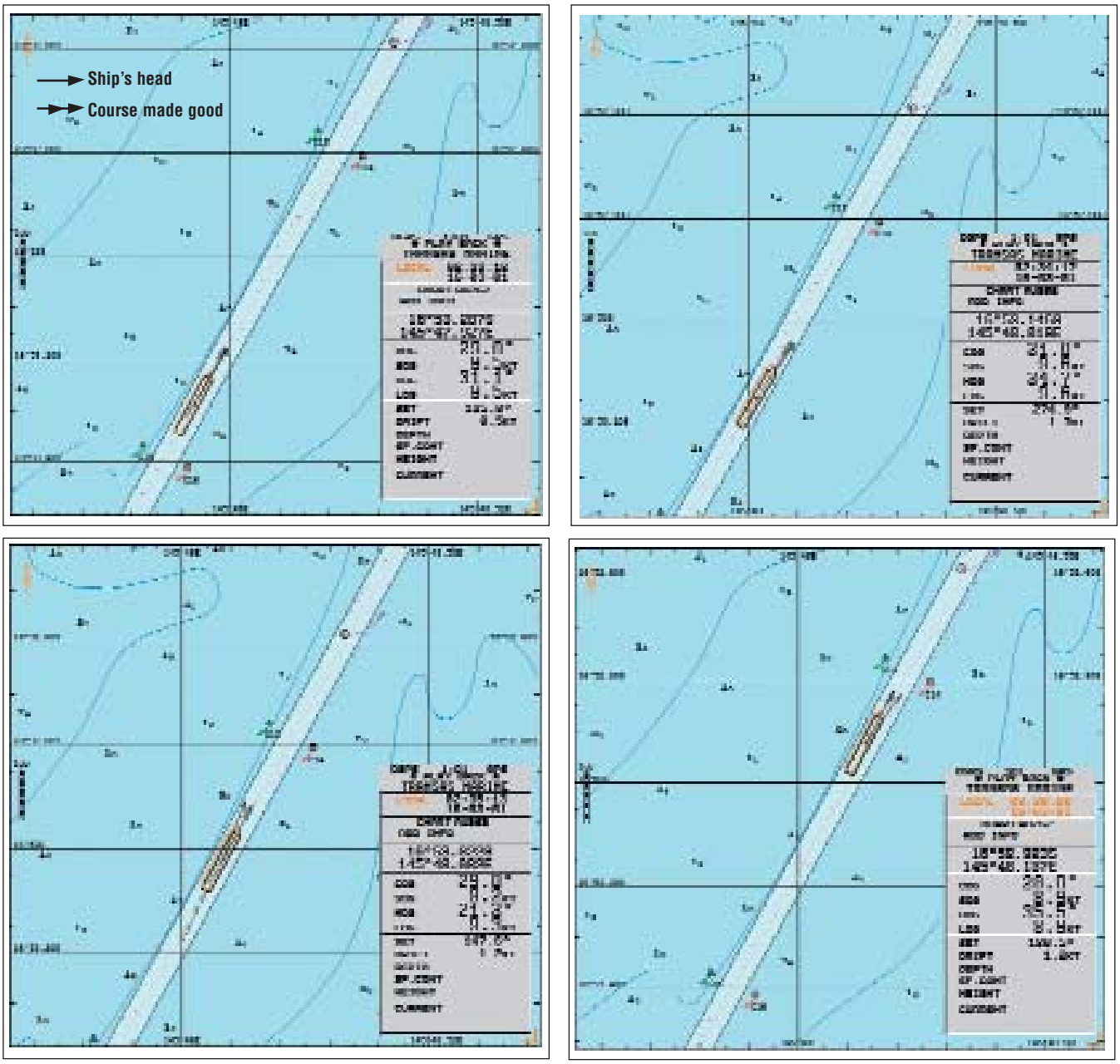
*Regal Princess* has a beam-to-draft ratio of 3.98 and has a typical modern cruise liner profile with a large windage area of about 7000 $m^2$. This would create approximately 38 tonnes force in a 20-knot beam wind. This force and the beam-to-draught ratio make the ship susceptible to large leeway in any significant wind.

The dimensions of the channel are therefore critical factors in the ship handling characteristics of a ship manoeuvring within the channel. The water displaced by the ship's forward motion must flow under and along the sides of the vessel. If the channel is narrow and the depth of water either side of the channel relatively shallow, the problem of displacing the water caused by the ship's passage creates a blocking effect. In such constricted conditions an increase in velocity of the water flow is created, which results in a decrease in pressure (the Bernoulli effect). This pressure decrease causes vessel responses such as squat and bank effect.

Cairns channel is 90 m wide, with a declared depth of 8.5 m. The charted depth of water outside, either side of the channel is 2.1 m. Even with 2 m of tide the dynamics set up by the water resistance and the acceleration of water past the hull within the channel confines would have affected the ship's manoeuvring characteristics.

4 Bank effect: The effect of a bank on a ship in narrow channels, causing bow cushion and stern suction.

**FIGURE 2:**
**Prinouts from the ECDIS recording for minutes 33,34,35 &36 just prior to the grounding.**




The recommendations of PIANC[5] for minimum channel width for this ship may be assessed using section 5.3 of the final report of the joint PIANC-IAPH[6] working group. The assessment takes in a number of factors, the sum of which gives the multiple by which the channel should exceed the ship's beam (B). Relevant factors for the Cairns approach channel, as applied to *Regal Princess*, are set out in the table on page 13.

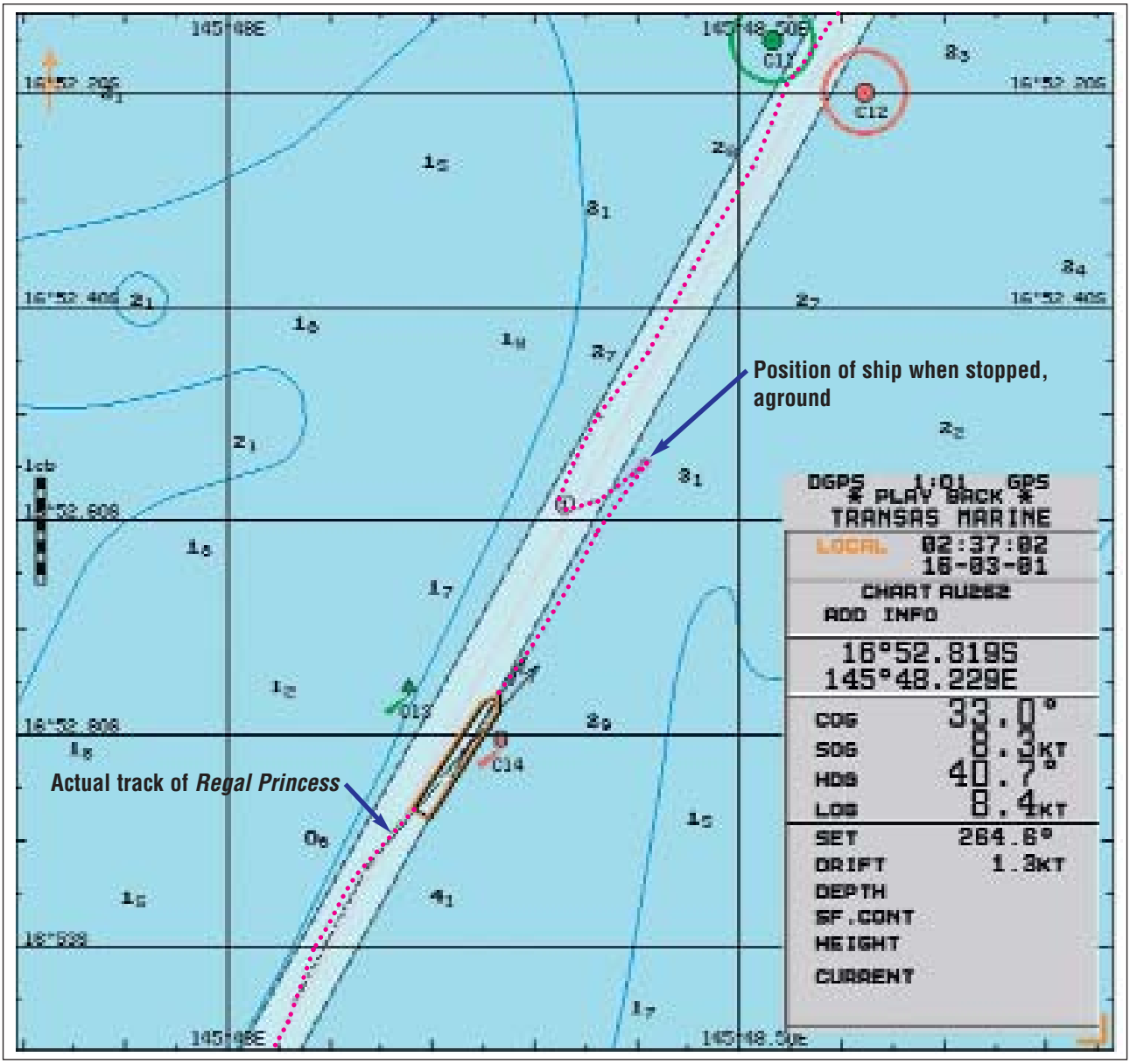
Based on these criteria, the design channel width would ideally have been 116 m or more. Even in the event that the ship's manoeuvring characteristics had been rated as moderate, a score of 3.3 B would have given an ideal minimum channel width of 106.5 m.

Given the width of the channel, with *Regal Princess* in the centre, the maximum leeway that could be applied before the extremities of the ship would cross the toe lines was 8°.

5 Permanent International Association of Navigational Congresses, Approach Channels, A Guide for Design, Section 5.3

6 IAPH International Association of Ports and Harbours

**FIGURE 3:**
**Printout from the ECDIS simulator as ship crosses toe line.**




| *PIANC Factor based on moderate ship's speed (8-12 knots)* | *Width factor 15/16 March 2001* |
|---|---|
| Basic manoeuvring lane width based on ship manoeuvrability* | 1.8 B |
| Vessel speed | 0 |
| Prevailing cross wind | 0.4 B |
| Prevailing cross current | 0.1 B |
| Prevailing longitudinal current | 0 |
| Significant wave height | 0 |
| Good aids to navigation | 0 |
| Bottom surface<1.5T smooth and soft | 0.1 B |
| Depth of waterway <1.25T | 0.2 B |
| Cargo hazard level | 0 |
| Moderate sloping channel edge (0.5 X 2) | 1.0 B |
| Channel width | 3.6 B |

The ship also had an approximate 'channel blockage' factor of about 0.29 and 'S2' factor[7] of about 0.41 for this port this time. These ratios are quite high. Channel blockage is a major factor in the propensity for a ship to squat.

Squat, the loss in under keel clearance as a ship moves from being stationary to being under way[8], is an important consideration when considering the general handling characteristics in shallow water. Squat increases with speed.

The vessel is provided with builder's tables giving predicted squat at different speeds for varying depth/draught ratios. The ship had a channel depth/ship draught ratio of 1.22 (or a UKC of 22 per cent). Under 'Ship Manoeuvrability' the PIANC Guidelines notes:

> As depth/draught ratio reduces to about 1.3 to 1.5, the ship may become slightly less directionally stable and more 'twitchy'. As the depth/draught reduces still further the vessel may become more directionally stable until at very low under keel clearances (depth/draught ratios of 1.05 to 1.10) it turns very sluggishly indeed. This improvement in directional stability is an advantage in a straight channel if the ship is not deflected from its proper course. But, if it is, its sluggish response may give handling problems and therefore require additional room to manoeuvre.[9]

However, squat is highly variable and assumptions that a passenger ship (usually associated with a fine form) would squat by the stern, may be erroneous depending upon the ship's centre of gravity. Millward (1996) observed:

> At present empirical methods exist for predicting squat and the evidence suggests that the predictions of squat are likely to be reasonably accurate (giving an answer to within 10 percent of the actual squat) and, if in error, are likely to err on the side of safety in that they predict a larger value of squat than will actually occur. These methods use the leading hull parameters together with the speed of the ship and depth of water and can be evaluated using a calculator. If a more accurate prediction is needed, then it is recommended that a method should be used which is restricted to the type of ship and the range of depths of water being considered.[10]

The results of the 1996 trial in Cairns, using the cruise ship *Crystal Symphony*, are consistent with the above article in that they provided indicative squat figures for that vessel (and possibly others of similar form) in a particular set of conditions. Such results could reasonably be used as a guide when considering port entry, so long as the limitations of the study are duly considered.

The small depth-to-draught ratio would have resulted in greater directional stability.[11] This means that the vessel is more sluggish in its response. The blockage factor would have resulted in a relatively high acceleration of water past the hull, setting up significant interaction effects with the bottom of the channel and the banks.

The UKC of 22 per cent is well within typical guidelines for UKC. The conclusion must be that there was adequate water under the keel. However, the beam-to-draught ratio and blockage factor, coupled with the limitations that the single rudder imposed on the ship's ability to steer, were all factors in the grounding.

## Single rudder/twin screw configuration

The effect of a ship's rudder is greatly enhanced by the flow of water generated by the propeller

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7 S2 factor is the ratio between the ship's midship cross sectional area and the cross sectional area of the channel minus the ship's midship cross sectional area.

8 Dr C B Barrass, Ship Squat, *Seaways*, January 1998, page 27

9 Ibid, PIANC Guide Section 5.3.6.1, p 22

10 Millward, A. (1996). A review of the Prediction of Squat in Shallow Water, *The Journal of Navigation*, Volume 49, Number 1, pp 84-85

11 Ibid PIANC Guide, Section 5.2.3.1

across the rudder surface. Single screw/single rudder ships, or ships with twin screws and twin rudders, experience accelerated water flow from the propeller flows directly over the rudder blade, enhancing manoeuvrability even at slow speeds.

In the case of the twin screw, single rudder configuration of some ships, the accelerated water flow from the offset propellers does not pass over the rudder, which is set on the vessel's centre line. In fact the flow over the rudder blade, is relatively slow until significant headway has been gained.

It was reported that *Regal Princess* had good steering characteristics at full speed but, at speeds under 10 knots, the single rudder had limited effect.

The bow and stern thruster units can compensate for the lack of rudder response at very low speeds (less than 4 knots). The effectiveness of the thrusters, even at very slow speed depends upon the point in the ship's length about which the vessel pivots. With the ship stationary, this point is amidships. Making headway, the pivot point moves forward and making sternway the point moves aft. The actual position of the pivot point depends upon the ship's length to beam ratio, but it can usually be assumed to be about 25 per cent of the length, from the bow, when making headway. The point moves aft of amidships, to about 75% of the length, when making stern way. When making headway the stern thruster generates a larger turning lever, while that of the bow thruster is diminished. This effect is reversed when making sternway.

When making way either ahead or astern, the velocity of water passing the thruster tunnels, together with vortices created by the hull, will reduce the effect of both bow and stern thrusters and, because of the possible creation of bow pressure, can have an opposite effect to that intended. Above 4 knots, thrusters have little, if any, effect.[12]

With the effectiveness of the rudder significantly reduced due to the slower water flow over it, and the bow thrusters being only effective under 4 knots, *Regal Princess* suffers a substantial limitation in manoeuvrability in the speed range between 4 and 10 knots. Using differential engine revolutions is not an effective solution.

> The control of ships does pose a very peculiar set of problems. The ship is a 'slow system' in which feed-back is not available in a direct and immediate form due to the enormous inertia of the vessel and the fluid nature of its physical environment. The navigator must thus take action in anticipation of what the situation will be at some time in the future.[13]

The ship had to be kept in the centre of the channel by use of the rudder and engines. Once off the centre line, the dynamics of the water flow past the hull on either side would vary, setting up turning and interactive forces. As the ship approached a section of bank, forces would tend to repel the bow and attract the stern (and increase the squat effect). The magnitude of these forces varies with the square of the speed of water flow. The other force that will become present is the longitudinal force on one side of the bow when making headway should the ship commence yawing. These two forces can compound and rapidly cause the ship to yaw heavily and, when in the confines of a narrow channel, quickly contact either bank.

These limitations in manoeuvring were compounded by the effect of the wind. However, the degree to which the ship was affected by the wind is not clear. The ship's log book records that, at 0400, when at anchor some one hour and 15 minutes after the grounding, the wind was from the south-east at force five (17 to 21 knots). Eyewitnesses within the enclosed wheelhouse

12 Reference: Hensen, H., (1990), Effectiveness and Use of Bow and Stern Thrusters, The Nautical Institute on Pilotage and Shiphandling.

13 Bryant, D., De Bievre, et al, The Human Element in Shipping Casualties, Phase II, Tavistock Institute, London

stated that there was very little wind, the ship being sheltered by the high ground to the south of Cairns, from beacon 18 outwards. The visibility was good. The master, in his accident statement, recorded the wind as being south-east at 25 knots. While the Cairns airport records indicated wind speeds from 8 to 12 knots, both the meteorological observer and the harbour master stressed that wind speed in and about Cairns is very localised and can vary significantly over a relatively small distance.

Whatever the effect of the wind, the evidence from the electronic chart display is that, from 0233 onwards, the ship developed a series of yaws and interactions with the channel boundaries that could not be recovered by use of the rudder.

Given the cross wind and the ship's size and draught relative to the channel dimensions, the systems in place to prevent the ship grounding (in accident model terms, the 'defences') were rendered ineffective, or at best marginal. In the Inspector's opinion, given the limitations on the ship's manoeuvrability, *Regal Princess* is unsuitable for this channel.

## The channel

A minimum channel depth of 7.9 m LAT had been promulgated to pilots by temporary Queensland marine notice 086 (T) of 2001.

Based on a survey conducted between 7 and 15 March, the 7.9 m limiting depth was mainly confined to the eastern toe line adjacent to beacon C18, between C14 and C10 and between C6 and C4. The channel toe line on either side of C13 also showed depths of 7.7 to 7.9 m. Also depths of 8.1 m and 8.2 m were shown in the channel 250 m north of C18 and about 750 m south of C18 indicating silting over this area of the channel. Other areas where the depth was less than the 8.3 m promulgated as the channel depth included areas between C16 and C10 and areas within the channel but adjacent to the toe line seaward of C10. Isolated spot soundings of 8.2 m were indicated within 25 m of the mid-channel line.

The dredging of the approach channel and its dimensions are a commercial matter for the port authority to determine. In the Inspector's opinion, given the channel's present configuration, the acceptance into the port of large twin screw, single rudder ships as a routine operation is outside the limits of a reasonable safety envelope.

## Cairns port and cruise ship size

Since 1998, some 25 cruise ships of 150 m or more in length have visited Cairns; some of these ships have made multiple visits. All these ships were twin screw vessels. Eight of these ships were more than 200 m in length and two of these have been 260 m or more in length (the longest ship being 264 m). Five of the eight ships over 200 m have been equipped with twin rudders.

The harbour master's approval and the conditions imposed were based on the information provided and the experience of other 'oversize' ships visiting the port. The harbour master is in a position to decline to accept a ship.

The consequences, however, of refusing entry to a ship are significant. In 1996 a study revealed that Cairns seaport generated directly, and indirectly, economic input to the region worth about 1.3 billion Australian dollars. This in turn generated incomes of about $320 million and created over 10,400 jobs, equivalent to 9% of the region's workforce.

There is therefore considerable commercial incentive, for those that benefit directly from the visit of cruise liners, to apply pressure to the approving authority to stretch the safety envelope.

However, there is concern among local tour operators that another incident will negatively

impact on the cruise industry's perception that Cairns is a safe port to visit. One senior industry representative went so far as to predict a 50% decline in passenger ship visits if this incident was repeated.

Following the grounding of *Regal Princess* the Maritime Division of Queensland Transport commissioned an external review of current management systems within the Port of Cairns. The key purpose of the review was to examine the criteria governing the vessel assessment process for ships entering the port of Cairns and to develop criteria through the adoption of a risk-based protocol.

The review resulted in a number of recommendations. The most significant of these was that the port adopt a quantitative measure of risk assessment, the Vessel Assessment Model (VAM). This model rates a ship's dimensions, propulsion system, steering characteristics and other relevant ship features, together with environmental factors such as weather, for both the Cairns channel and the port. The ship's score is compared with a minimum bench-mark.

The VAM provides a quantifiable measure of a ship's suitability, giving greater certainty to what had hitherto been a largely subjective assessment of the risk based on basic ship parameters.

## Bridge Resource Management

The proper conduct of *Regal Princess* relied heavily on good bridge team work or 'bridge resource management'. This requires the pilot and the ship's bridge team to be working from the same knowledge base. It also requires preparatory work by both the pilot and the ship's staff.

Following the meeting to reschedule the sailing time, and knowing that the pilot had concerns over the handling characteristics, the master could have simulated the departure on the ship's on-board simulator. This may have provided useful information to the whole bridge team. There is no evidence that the master conducted such a simulation. The pilot was not made aware of the existence of this simulator.

On sailing, the bridge team was adequate. After clearing the berth the pilot had the con, the master was at the telegraphs, the staff captain at the thrust controls and the OOW maintaining a plot of the ship's position. Given the known poor manoeuvring characteristics of the ship at slow speed, the narrowness of the channel and the reduced UKC, it was important that the team should operate in concert and the pilot be fully aware of engine settings, rudder angles etc.

Witnesses suggested that the thrusters were being used and engine revolutions altered without an order by, or reference to, the pilot. The pilot stated that approaching beacon 14 at, or just before, 0233, the helmsman was unable to steer and had applied full port rudder, but the ship's head started to swing to starboard. Soon after this, as the vessel was close to beacon 14, the pilot was told by the master that the port engine was going astern. This was followed by a pronounced series of sheers to starboard and to port before the ship took the ground at about 0237, coming to a stop at about 0240.

Information provided to the investigation is that some thruster and engine adjustments were made without the pilot's knowledge at various stages of the outward passage. Given the inherent problems of manoeuvring *Regal Princess* at slow speeds and the marked channel effects, the bridge resource management was less than optimal.

In submission Princess Cruises wrote:

> The Captain was undoubtedly concerned about the control of the ship and he would have taken such action as he thought necessary to regain control or minimise impact. In such cases the normal act of advising the pilot of his actions may have been by-passed due to the time factor. [Princess Cruises] do not think that the observation that the bridge resource management

was less than optimal is correct and should be removed.

## The pilot

The pilot assigned to *Regal Princess* had been at sea since 1969, initially with the Royal Australian Navy and latterly the merchant navy with experience as a deck officer on tankers. He joined the pilot service in 1998, serving eight ports in far north Queensland.

Since October 1998, the pilot had undertaken a total of 21 arrival and departure passages at Cairns. The largest ship he had handled was a bulk carrier of 253 m in length. In 2000 he piloted three cruise ships in and out of Cairns, two of which (at 189 m and 195 m respectively) were of twin screw, single rudder configuration.

On 15 March, he had experienced problems handling *Regal Princess* during the inward passage. Through his initiative, the sailing time was rescheduled to a time when the under keel clearance was greater and the wind may have been expected to have abated.

The evidence is that the pilot was suitably qualified and had experience of twin screw, single rudder vessels.

This pilot was not the senior pilot of Ports Pilots Queensland. However, given the size and characteristics of *Regal Princess*, together with the wind that persisted into the morning of 16 March, there is no evidence that any other pilot would have prevented the grounding.

Before boarding the ship, the pilot was not aware that *Regal Princess* was a single rudder ship, that there was a speed restriction, or of other basic information about the vessel. However, much of the information had been viewed by the duty pilot as part of the port entry approval process. One key fact that had not been identified at any stage of the approval process is that *Regal Princess* had a single rudder. This information was not available from normal reference sources such as Lloyd's Register and was not provided by any other source, such as the ship's agent.

There was some conflicting evidence as to the effectiveness of the flow of information within the pilot service. The nature of the service, which involves providing pilots for up to nine ports over a wide area of Far North Queensland, has the potential for a disrupted or incomplete information flow.

## Princess Cruises – Risk Assessment

As part of the investigation, the Inspector asked Princess Cruises Ltd for information on any risk assessment that may have been undertaken for their cruise ships visiting the port of Cairns. The operators responded that Princess Cruises had no copy of any risk analysis and that they were unaware of any such analysis having been undertaken. The operators noted that Princess Cruises marine staff, who would have been involved in any evaluation of the port of Cairns had either retired or left the company.

In submission, Princess Cruises outlined their normal process of assessment for a port as:

- Information is received from the port.
- Evaluation of the information, including the type/size of cruise ships that have called.
- Confer with Princess Cruise Captains, who are familiar with the port and ship-type intended to call.
- If necessary send a Captain to the port to evaluate.

In the case of the port of Cairns, the first three bullet points were carried out. As a number of the Captains were familiar with the port and a number of our ships have already called, there was no need to send a Captain to the port to evaluate. Captains upon arrival at a port, may, on the grounds of safety, abort a port call.

When the investigator asked for a copy of a risk analysis it appeared that he required a particular type of document, the format of which does not exist at Princess Cruises. The investigator was advised that Princess had no such formal analysis. There was no further communication with the Marine Department to discuss our port assessment process. Your comments on our port assessment process are incorrect and should be removed.

The Inspector had made two approaches to Princess Cruises. The first, by facsimile on 24 August 2001, asked,

' . . . I understand that a few years ago a risk analysis was undertaken relating to visits by cruise ships such as *Regal Princess* to the port of Cairns, Queensland Australia.

It would be of great assistance to our investigation if you could please provide a copy of that analysis, together with any other relevant information, so that we may make a comprehensive, objective assessment of the grounding.

A reply was received on 31 August by e-mail:

'Thank you for your facsimile of 24/08/01. Unfortunately I do not have a copy of the risk analysis that you refer, and am not aware of any risk analysis being carried out.

If I can be of further assistance please contact me.'

On 4 September the Inspector sent the following e-mail to Princess Cruises:

'I now understand that a hydrodynamic risk analysis was conducted by Crystal Cruises on behalf of P&O.

My main concern is that, given the beam, draught and channel blockage ratio and the single rudder configuration of *Regal Princess*, there seems to be no assessment of any risk or difficulties that a vessel of *Regal Princess*'s [size] might encounter.

If you have the above survey or any advice on the issue of a single rudder ship, I would be most grateful if you could supply it.'

Princess Cruises replied on 11 September:

'Again I have to advise you that I am unaware of any such survey conducted. The marine personnel in our office most closely involved in evaluating the port of Cairns have either retired or left the company.

I cannot conceive of any situation whereby we would have Crystal Cruises carry out any survey on our behalf.

The Inspector did contact a retired, former, senior master who had command of Princess Cruise liners entering Cairns and later held a senior management post ashore. He was on board in his operational management capacity in August 1997 when the P&O cruise ship *Fair Princess* (185 m LOA, 34.5 m beam and 8.9 m draught) experienced steering difficulties at Cairns. In view of problems experienced during the inward passage the pilot retained a tug on the headline on the outward passage. Significant engine movements were used to overcome a steering problem. The pilot commented in his report:

'Without the tug already on a head line I doubt a grounding could have been averted'.

The Inspector wrote:

'I understand that while you were in command you made recommendations to P&O Cruises relating to the suitability of cruise ships that might be required to visit Cairns. I would be most grateful if you could tell me what those recommendations were, the date you made them, to whom they were made and whether your recommendations were acted upon. If your recommendations were not adopted, are you aware why they were not?'

The former master replied:

I cannot recall any occasion both when I was at sea or working ashore that my recommendation as to the unsuitability of a port was ignored."

In preparation for a visit by the P&O cruise ship *Sky Princess* (240 m LOA, beam 27.8 m and draught 8.15 m) in January 1998, the master sent a facsimile to the agent with advice to the harbour master.

'For your guidance the steering gear and small rudder are the same as before. However, the stern thruster is effective to 70 per cent efficiency to 5

knots, falling off to 0 percent at six knots. Using both thrusters and engine the ship can be manoeuvred against winds up to 20 knots, without tug assistance.

Any steering difficulties will occur in the dredged approach channel, which is not safe for this ship to transit in wind speeds over 12 knots.'

Information received by the investigation indicates that the subject of risk assessment for vessel port visits had, in the past, been raised within Princess Cruises, including for the port of Cairns. This followed a number of problems experienced in the Caribbean, and elsewhere, with ships having such high windage areas, particularly affecting the stern. A recommendation had also been made earlier that the company's two twin screw/single rudder vessels, *Regal Princess* and *Crown Princess*, should remain on the Caribbean run, and only twin-rudder vessels should visit Cairns. This recommendation, however, was not acted upon, commercial considerations having taken precedence. Previous, successful, visits by these ships were cited as sufficient reason for continuing the practice.

In submission Princess Cruises stated:

The *Regal Princess* and *Crown Princess* since their introductions in 1990 and 1991 respectively have cruised successfully in the Caribbean/Mediterranean/Northern Europe/Eastern Seaboard of North America, including the St Lawrence river/Western Seaboard of North America, including British Columbia and Alaska/The Far East/Hawaiian Islands/The South Pacific/Australia. This comment has no merit or substantiation.

An earlier grounding is mentioned on page 10 of your report. This occurred on the approaches to Charlotte Amalie in the US Virgin Islands. The cause of this incident was attributed to human error.

*Crown Princess* has completed three successful seasons in Northern Europe. On this itinerary she enters the port of St Petersburg via a long dredged channel 80 meters wide. It is open to the elements and is not dissimilar to the channel at Cairns.

In the Inspector's opinion, the effect of a lack of a risk assessment is to place the entire onus on the port authority for the safety of the ship, whereas it is the operators who should best appreciate the manoeuvring characteristics and limitations of their ships.

It seems incredible to the Inspector that a major asset, involving a considerable number of passengers and crew, should be committed to a port without any form of risk or safety assessment being undertaken by the ship's operators.

## Vessel approval system

The approval system for this visit by *Regal Princess* to Cairns was progressed via the Passenger Ship Notification form. The form was not completed in its entirety. This form communicates such detail as engine type, number and type of propellers and rudders, thrusters etc. The significance of the required information and its required level of accuracy was not fully appreciated by all involved and the form was accepted even though some important details were not completed.

This form had undergone some recent revisions but the timeliness of submission and approval was the subject of discussions among all the involved parties.

## Fatigue

Both the pilot and the master would have started duty at about 0430 on 15 March. Following the berthing of *Regal Princess* the pilot returned to his home and attended to some pilotage management issues. In the afternoon, at 1500, the meeting to review the sailing time involved the pilot and master. Both were on duty, with other ship's staff at 0200 on the morning of 16 March.

The hours of both the pilot and the master were subjected to analysis through the InterDynamics Fatigue Index Program. Despite the hours that the master had been awake (from early morning for arrival, during the day and evening) the master recorded an index score that would not suggest that fatigue was a factor. The pilot's score also indicated that the pilot was operating below the fatigue threshold.

## Drugs and alcohol

There was no evidence that either drugs or alcohol were in any way involved in this incident.

# Conclusions

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

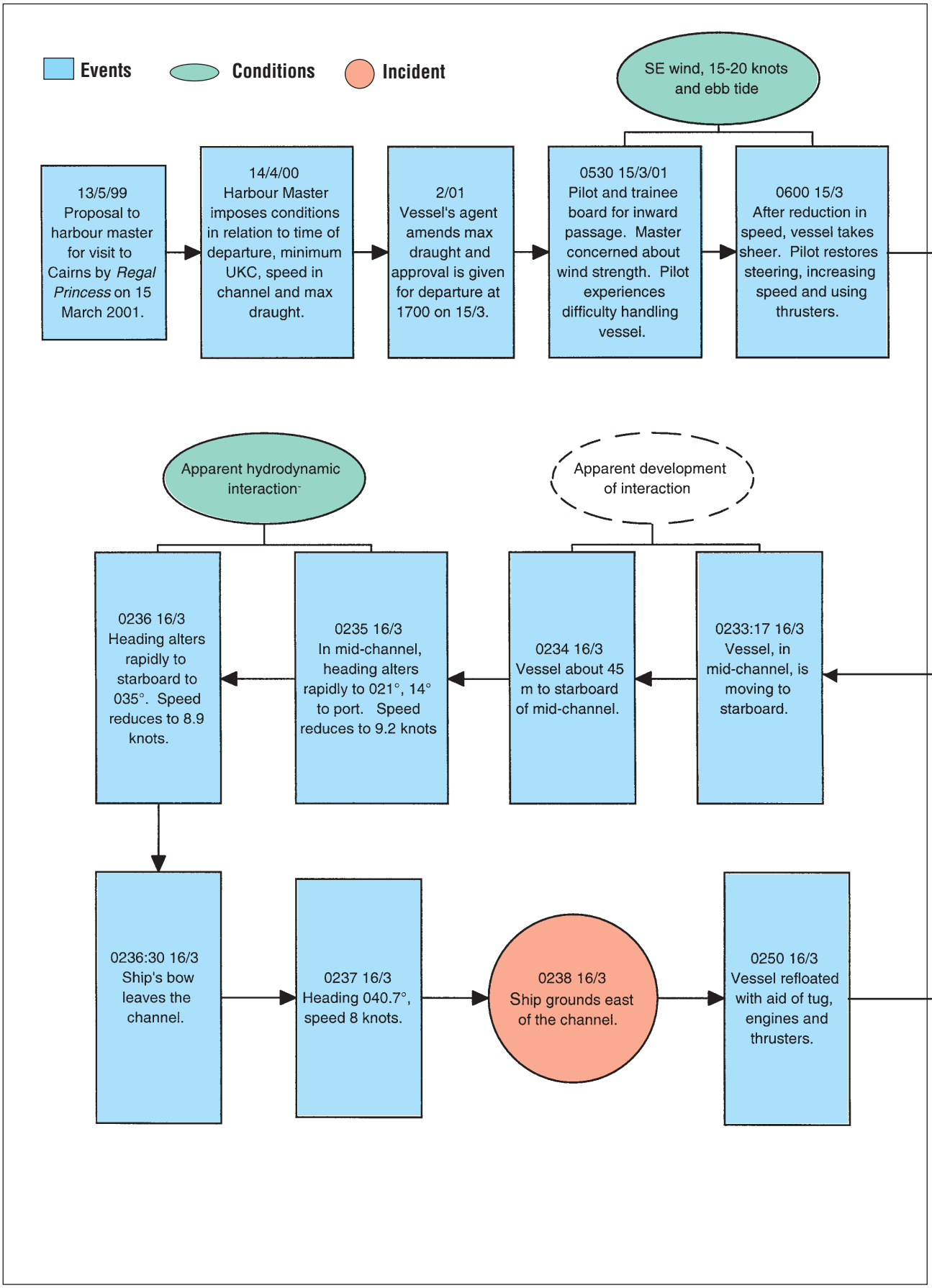
Based on the evidence available, the grounding occurred because control of the vessel was lost during the channel transit commencing at about beacon C16. The following factors are considered to have contributed to that loss of control and hence to the incident:

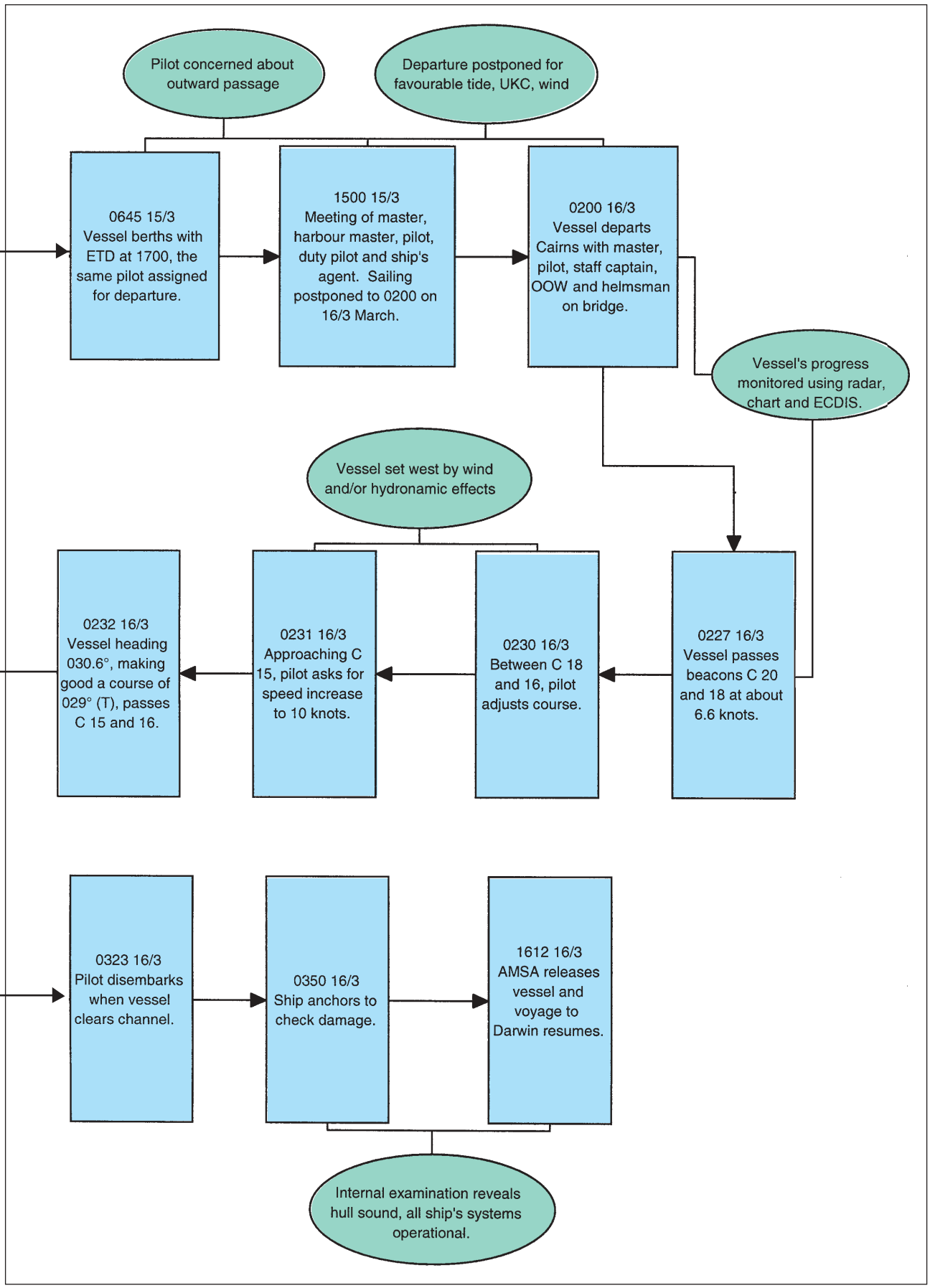
1. The dimensions of the Cairns port channel are too restrictive for *Regal Princess*.
2. There are inherent restrictions in this ship's manoeuvrability between 4 knots, the limit of thruster effectiveness, and 10 knots when the vessel's single rudder has reasonable effect.
3. The lack of a risk/operational assessment for Cairns port by Princess Cruises exposed the ship to a foreseeable, but unnecessary, risk.
4. Bridge Resource Management practices were less than optimal.
5. At the time of the grounding of *Regal Princess*, the Cairn's port approval procedures for vessels over 200 m in length and 32 m in beam, while identifying the ship dimensions and probable manoeuvring characteristics, lacked a formal risk assessment process.
6. The commercial incentives for accepting large cruise ships into the port may have influenced the approval process to exceed the limits of a reasonable safety envelope.

Although not directly contributing to this incident, it is also considered that there was a lack of effective communication between the various interested parties, and within the pilot service.

It is also considered that there was no objective evidence to indicate that undue fatigue was a factor in this incident. There was no evidence that drugs or alcohol were in any way involved in the incident.

**FIGURE 4:**
***Regal Princess*: Events and causal factors chart**




Pilot concerned about outward passage
Departure postponed for favourable tide, UKC, wind
0645 15/3 Vessel berths with ETD at 1700, the same pilot assigned for departure.
1500 15/3 Meeting of master, harbour master, pilot, duty pilot and ship's agent. Sailing postponed to 0200 on 16/3 March.
0200 16/3 Vessel departs Cairns with master, pilot, staff captain, OOW and helmsman on bridge.
Vessel's progress monitored using radar, chart and ECDIS.
Vessel set west by wind and/or hydronamic effects
0227 16/3 Vessel passes beacons C 20 and 18 at about 6.6 knots.
0230 16/3 Between C 18 and 16, pilot adjusts course.
0231 16/3 Approaching C 15, pilot asks for speed increase to 10 knots.
0232 16/3 Vessel heading 030.6°, making good a course of 029° (T), passes C 15 and 16.
0323 16/3 Pilot disembarks when vessel clears channel.
0350 16/3 Ship anchors to check damage.
1612 16/3 AMSA releases vessel and voyage to Darwin resumes.
Internal examination reveals hull sound, all ship's systems operational.

# Recommendations

1. Trials should be implemented to examine the effectiveness of tug, or other external assistance, for large vessels with limited manoeuvring characteristics and rudder effect that are required to use the Cairns port channel.
2. In view of the increasing size of cruise ships that may be expected to visit Australian ports, Queensland Transport should assist those responsible for assessing ships for access to Queensland ports by refining their Vessel Assessment Model or developing a suitable alternative quantitative model. Such a model should take into account the particular characteristics of any given ship and would build on the existing initiative to provide a quantitative bench mark to assist the decision makers.
3. Cairns Port Authority should assess the possible cost benefit of modelling the Cairns approach channel and harbour to accurately simulate the behaviour of large ships entering and sailing from Cairns.
4. Princess Cruises should undertake a risk assessment of the port of Cairns.
5. Ports Pilots Queensland, together with ships' agents and other interested parties, should review their communications procedures and practices and information gathering procedures, to ensure that all duty pilots have all available information on the ships they are to pilot.

# Submissions

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

Relevant parts of the final draft were sent to Princess Cruises, the master, staff captain, second officer and third officer of *Regal Princess*, Queensland Transport, the regional harbour master Cairns, pilot and duty pilot, Port Pilot's Queensland Pty Ltd, the Cairns Port Authority, and Barrier Reef pilots.

Acknowledgment of the draft report was received from the third mate of *Regal Princess*, the pilot, and the Australian Reef pilot.

Submissions and further information were received from Princess Cruises, Queensland Transport, the Cairns Harbour Master, the duty pilot, Port Pilot's Queensland Pty Ltd. Where appropriate the text has been amended. In other instances the submission has been included in the report.

# *Regal Princess*

| | |
|---|---|
| IMO Number | 8521232 |
| Flag | British |
| Classification Society | RINA |
| Ship Type | Passenger |
| Builder | Fincantieri, Italy |
| Year Built | 1991 |
| Owner | Princess Cruises Inc |
| Ship Managers | Princess Cruise Lines |
| Gross Tonnage | 70 285 |
| Net Tonnage | 35 113 |
| Displacement (8.1m draft) | 36 575 tonnes |
| Length overall | 245.06 m |
| Breadth moulded | 32.25 m |
| Distance bridge/bow | 45.89 m |
| Distance bridge/stern | 199.17 m |
| Engine | 4 x MAN - B&W 8L 58/64 medium speed |
| Power | 37 640 kW |
| Propulsion | 2 x 12 000 kW electric motors |
| Thrusters | 2 x bow thrusters, 1 780 kW total<br>2 x stern thrusters, 2 575 kW total |
| Propellers | 2 x fixed pitch, 6 bladed |
| Rudder | 1 semi-balanced on the centreline |
| Normal crew number | 660 |
| Normal passenger capacity | 1596 |

**Independent investigation into the grounding of the British flag passenger ship Regal Princess in Cairns Harbour Queensland, on 16 March 2001**

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