Report 06-007, Kawasaki-Hughes 369HS, ZK-HDJ, collision with terrain, Mount Ruapehu, 11 December 2006

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Kawasaki-Hughes 369HS
ZK-HDJ

collision with terrain

Mount Ruapehu

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Abstract

On 11 December 2006, a Kawasaki-Hughes 369HS helicopter, registered ZK-HDJ, took off with the pilot and 4 passengers on board from near Crater Lake on Mount Ruapehu, at an elevation of about 8300 feet. The pilot could not climb the helicopter above the surrounding terrain, so he descended towards the lake to accelerate the helicopter towards its best-angle-of-climb speed. The helicopter hit the lake surface and came to rest on the shore of the lake. All of the occupants were injured and the helicopter was destroyed.

Safety issues identified included:

- the training and supervision of helicopter pilots working in mountainous terrain
- the removal of seats and the disregard for the wearing of seat belts in helicopters
- the carriage of life jackets on flights where, in the event of a forced landing, a water landing was likely or preferable
- the effectiveness of the Civil Aviation Authority's current audit and surveillance programmes for determining the true level of industry compliance.

Photograph courtesy of Helistar Helicopters

Kawasaki-Hughes 369HS, ZK-HDJ

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Abbreviations

°C	degrees Celsius
CAA	Civil Aviation Authority of New Zealand
DOC	Department of Conservation
ft	foot, feet
ISA	International Standard Atmosphere
kg	kilogram(s)
lb	pound(s)
m	metre(s)
RPM	revolutions per minute
UTC	coordinated universal time

Glossary

autorotation	(descending) flight with the rotor powered by aerodynamic forces rather than the engine
commercial transport operation	(in the context of this report) an operation for the carriage of passengers or goods by air for hire or reward where the passengers or goods are carried to or from a remote aerodrome
density altitude	the altitude in the ISA at which the air density would be equal to that at the place of observation. Density altitude is pressure altitude corrected for non-standard temperature. In general, as density altitude increases, aircraft performance decreases
flare	to incline the rotor disc rearwards so that the rotor thrust acts to decelerate the helicopter
ground effect	a condition of improved performance due to the airflow through the rotor disc combining with the cushion of higher pressure air over the surface below the helicopter
hectoPascal	the pascal is the unit of pressure in the metric International System of units. A hectoPascal is 100 pascal
over-pitch	when the blade pitch angle is increased to such an extent that rotor RPM cannot be maintained
pressure altitude	indicated altitude corrected for non-standard sea level pressure
remote aerodrome	(in the context of this report) any structure or any area of land or water used for take-off or landing to which access by road or water is restricted, limited or obstructed by geographical conditions
translational lift	an improvement in performance caused by increased airflow across the rotor. The effect is present over an airspeed range of approximately 15 to 25 knots, depending on the helicopter type

Data Summary

Aircraft registration:	ZK-HDJ
Type and serial number:	Kawasaki-Hughes 369HS, 6638
Type of engine and serial number:	one Rolls-Royce (Allison) 250-C20B gas turbine, CAE-832828
Year of manufacture:	1977
Operator:	Helistar Helicopters Limited
Date and time:	11 December 2006, at about 1715[1]
Location:	Crater Lake, Mount Ruapehu latitude: 39° 16.9´ south longitude: 175° 34.3´ east
Type of flight:	commercial transport operation
Persons on board:	crew: 2 passengers: 3
Injuries:	crew: 2 serious passengers: 1 serious, 2 minor
Nature of damage:	helicopter destroyed
Pilot's licence:	commercial pilot licence (helicopter)
Pilot's age:	33 years
Pilot's total flying experience:	2735 flight hours, 625 flight hours on type
Investigator-in-charge:	P R Williams

[1] Times in this report are New Zealand Daylight Time, (UTC+13 hours), and expressed in 24-hour mode.

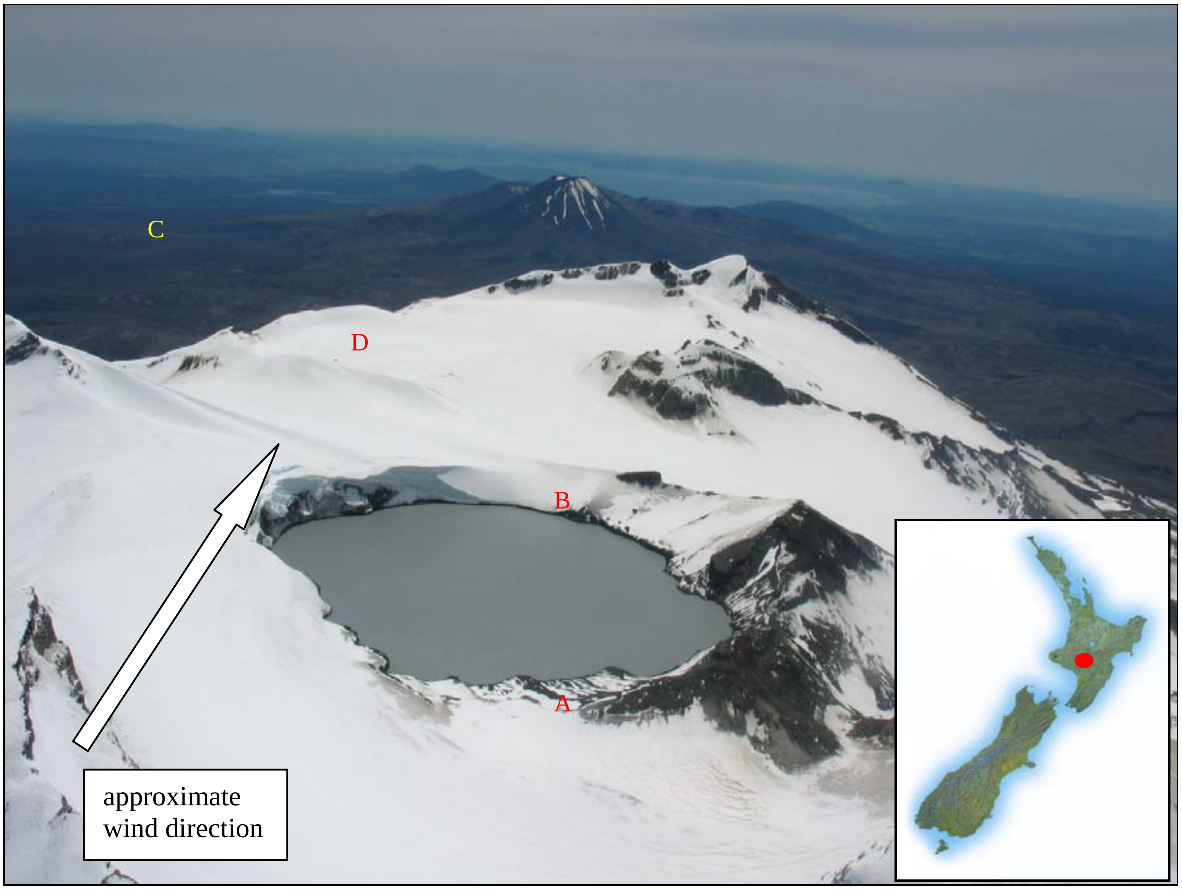

Figure 1
Mount Ruapehu Crater Lake, looking north
A = the outlet, landing and take-off site, B = accident site, C = earlier work area on lower slopes, D = Dome Shelter.

1 Factual Information

1.1 History of the flight

1.1.1 On 11 December 2006, a Kawasaki Hughes 369HS helicopter ("Hughes 500C"), registered ZK-HDJ, was being used to support 15 Department of Conservation (DOC) staff working on a weed control programme on the northern side of Tongariro National Park. The area included undulating terrain at an average elevation of about 3000 feet (ft)[2].

1.1.2 The DOC staff were being flown to find target plants and then they disembarked to eradicate them. The operation involved frequent short, low level flights with the staff often boarding and disembarking from the helicopter while it was in a low hover. To assist with rapid on-load and off-load of staff and to minimise damage to the cabin interior, the pilot had removed the doors, the front seat cushions and the seats in the rear cabin. All lap belts remained fitted, but some staff wore waist harnesses so they could secure themselves with karabiners to tie-down points in the rear cabin floor. The rear cabin floor was protected with a sheet of plywood.

1.1.3 December 11 was the first day of the annual programme and the third season the pilot had done this work for DOC. An employee of the operator acted as a crewman to assist with the loading and unloading of the helicopter and with refuelling. The pilot and crewman started flying that day at about 0945 and took a lunch break of nearly one hour.

1.1.4 Late in the afternoon, the pilot agreed to a request, advised by the supervisor of the weed task, to uplift a park ranger (ranger A) from a point high on Mount Ruapehu and return him to the park headquarters. The pilot understood that the pick-up was to be from near Dome Shelter (see Figure 1), where he had flown a DOC task previously. He also agreed to the supervisor's request that a ranger from the weed team (ranger B) go on the flight because ranger B was understudying ranger A's work.

1.1.5 After completing the weed task, the pilot and crewman re-fitted the doors and added sufficient fuel to the helicopter for the flight up the mountain and the return to their Taupo base.

1.1.6 On the flight up Mount Ruapehu, ranger B sat in the front right seat, secured with a lap belt, and the crewman sat on the rear cabin floor without any form of restraint. Both wore lightweight clothing appropriate for the weed clearing task at a lower level on a warm day.

1.1.7 Passing about 8000 ft altitude while approaching Dome Shelter, the pilot carried out a power check and determined that he had sufficient engine torque[3] available for the landing and take-off. He then realised from various radio calls that instead of one ranger to be picked up from Dome Shelter, there were 2 people waiting at Crater Lake outlet.

1.1.8 Ranger A and a scientist were engaged in a routine lake survey. They had alpine and helicopter experience and were equipped for alpine work and survival. Earlier that day, they had tramped to Crater Lake when high winds and low cloud prevented the use of a helicopter. At about 1530, while near Dome Shelter, the weather improved enough for ranger A to request helicopter recovery from the lake outlet. The survey team had time to walk down the mountain before nightfall if a helicopter could not recover them.

1.1.9 At about 1710, ZK-HDJ arrived near Crater Lake and ranger A radioed the pilot and advised him there was a slight north-east breeze. The pilot said later that small ripples on the lake surface had indicated there was a light northerly wind. Ranger B said there was some light turbulence as the helicopter approached from the east to land.

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[2] Altitudes and vertical distances used in aviation are expressed in feet. One foot = 0.305 metre.

[3] Helicopter turbine engine power is often measured by the torque applied to the transmission gearbox, and indicated in pounds per square inch of oil pressure.

1.1.10 The landing site was east of, and nearly 30 ft above, the lowest point of the lake edge, at an elevation of about 8330 ft (see Figure 2). The pilot said he needed very little power to land in “nice and steady” conditions.

1.1.11 After landing, the pilot left the helicopter and spoke to the survey team. They were surprised to see 2 additional passengers, because they could not recall ever having flown out of the lake in a Hughes 500C with 5 people on board. Ranger A asked the pilot if he could lift 5 people from the lake, or whether he might split the load and “shuttle” them to a higher site from which they could fly off the mountain together. The scientist also asked the pilot to hover over the ice cliffs in order to take a photo. The survey team recalled that the pilot said he would load them and their packs and “see how it goes”, or words to that effect. The pilot said later that he had been operating all day with similar or greater loads without any performance or engine problems.

1.1.12 The pilot did not ask for the weight of any of the passengers or packs, but he did help to load the packs, which the survey team estimated weighed 22 kilograms (kg) (48 pounds (lb)) in total[4]. The pilot said there were 200 lb of fuel on board and none of the passengers was large, so he concluded that the take-off weight would be under the maximum allowable gross weight.

Figure 2
Crater Lake, looking south
A = landing and take-off site

1.1.13 The crewman said he knew the helicopter would be heavy, but he was unfamiliar with the performance of the Hughes 500C. He later said that the helicopter was not overloaded in terms of the number on board, and he estimated that the survey team’s packs, which he had lifted during loading, weighed less than 7 kg (15 lb) each.

1.1.14 Ranger A sat on the left side of the rear cabin floor and the crewman on the right side, both without a lap belt fastened. The packs were on their thighs or on the floor between them. Ranger B sat in the centre front seat position with her lap belt unfastened and the scientist sat,

[4] The helicopter flight manual used the pound as the primary unit of mass. One pound = 0.454 kg.

with his lap belt fastened, at the front right seat position so that he could take photographs. The pilot had his lap belt and shoulder harness fastened.

1.1.15 Prior to lifting off, the pilot asked over the intercom whether everyone was "ready to go". The scientist and ranger A were the only passengers wearing head sets. The pilot could not see the rear cabin passengers, but because ranger A confirmed that the rear doors were shut, he got the impression that everyone was secure.

1.1.16 The pilot said the take-off conditions were perfect, with about 10 knots[5] of wind from the north. He said he lifted the helicopter into a low hover and saw the indicated engine torque "at the bottom of the yellow" range (of 56-64.5 pounds per square inch), which was enough spare power, he said, to conduct a vertical take-off. He said the engine was limited by the maximum allowable torque at that altitude, and the related power parameters of engine speed and temperature "were all OK".

1.1.17 The pilot said that he intended to remain in-ground-effect[6] and gain translational lift[7] while the helicopter was climbed up the rising ground to the east of the lake. He was then going to turn out of the crater and over the eastern side of the mountain. He said the take-off was normal, but "as soon as we started moving forward, it stopped climbing and I could see it was going wrong. I had no way out". The pilot said he then focused on finding an escape route and opted to descend towards the lake in order to increase the airspeed.

1.1.18 The pilot realised that he had no escape route and he exclaimed, "What was I thinking of?" and "Someone jump out!" Ranger A unlatched his door with the intention of complying with the pilot's instruction, but decided he might not survive a leap into the lake. The scientist undid his seat belt and tried to open his door to get out, but was prevented from doing so by the helicopter banking sharply.

1.1.19 As the helicopter neared the ice cliffs, both the pilot and the crewman heard the low rotor speed[8] audio warning, and the pilot then pulled up hard on the collective lever. The pilot said he did not deliberately flare[9] to reduce the forward speed, but some passengers described such a manoeuvre at the same time as the pilot yelled "Brace!" The helicopter appeared to some of the passengers to have hit the water and flipped or rolled before coming to rest (see Figure 3). Some of the occupants recalled hearing the engine winding down at this time.

1.1.20 Both front-seat passengers were thrown out, about 5 m towards the beach. Ranger B suffered a broken wrist. Ranger A was submerged, but escaped through the open left rear door. The pilot received a broken ankle and the crewman 2 fractured neck vertebrae. All of the occupants were cut and bruised and ingested highly acidic water that caused soft tissue irritation lasting for some days. They attended to each other's injuries and recovered items from the wreckage to help keep warm.

1.1.21 The pilot removed the emergency locator transmitter and fitted the removable aerial, but he could not tell if it was transmitting. He decided he was best able to walk out and seek help. At about 1725, he left the scene, taking the emergency locator transmitter with him, because he thought its signal would be more clearly received from outside the crater. Above the crater, he noted that the wind was from the south.

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[5] A knot is one nautical mile an hour, which equals 1.852 kilometres an hour.
[6] Ground effect is a condition of improved performance due to the airflow through the rotor disc combining with the cushion of higher pressure air over the surface below the helicopter.
[7] Translational lift is an improvement in performance caused by increased airflow across the rotor. The effect is present over an airspeed range of approximately 15-25 knots, depending on the helicopter type.
[8] Expressed as revolutions per minute (RPM).
[9] To flare means to incline the rotor disc rearwards so that the rotor thrust acts to decelerate the helicopter.

1.1.22 At about 1810, the pilot reached a ski field and met a party of trampers who used a cell phone to contact emergency services. The pilot then telephoned his wife and asked her to alert a local rescue helicopter pilot.

1.1.23 About 30 minutes later, as the Ruapehu Alpine Rescue Organisation was responding to the emergency, the scientist made radio contact with the DOC Duty Officer. The first helicopter got to the scene about 1900, the pilot was recovered from the ski field at 1935, and everyone was recovered to the park headquarters by 1950.

Figure 3
ZK-HDJ beneath ice cliffs

1.2 Site information and helicopter damage

1.2.1 The helicopter was destroyed by the impact with the lake surface and lake shore. Low cloud and high winds prevented wreckage recovery for about 65 hours. During that time, the corrosive lake water caused deterioration of the wreckage. Although the wreckage was prepared for recovery by a mountain rescue team and lifted out of the lake by an experienced helicopter pilot, further damage was unavoidably incurred.

1.2.2 The helicopter came to rest on the steep, narrow shore of the lake below an overhanging ice cliff approximately 30 m high. The fuselage faced the approximate direction of take-off with the left side submerged, but the tail boom was turned forward nearly 180^{o} and lay to the right of the fuselage. The forward windscreen and surrounding structure, including both front cabin doors, were torn off. The rear cabin retained its shape. The main rotor blades had damage consistent with having impacted while under power.

1.2.3 The site was dangerous because of frequent ice and rock falls, so inspection of the wreckage was delayed until it was recovered nearly 3 days later. Fuel continued to drain from the fuselage after it was placed on a truck for removal from the mountain. The wreckage was flushed with fresh water, but parts that had been immersed continued to corrode.

1.2.4 Examinations of the helicopter, its engine and the engine accessories were restricted by additional damage caused by corrosion while partially immersed in the acidic lake. However, findings were consistent with the pilot expressing confidence, shortly after the accident, in the performance of the helicopter and its engine that day.

1.2.5 When the wreckage was first inspected, the pilot's harness inertia reel was found jammed, but the right front inertia reel was functional. The right rear seat belt buckle was found fastened, and the left rear seat belt unfastened. The front seat lap belts were missing, having been unclipped from their anchor points when the seat squabs and carpets were removed for survival aids. The rear cabin plywood floor was missing.

1.2.6 Two main rotor blades were torn off the rotor hub and although most of those 2 blades were recovered, more than 2 m of their outboard ends were not found. The tips of the other 2 main rotor blades were intact, with one blade scratched on its upper surface over the 15 centimetres nearest the tip. Rotor head damage was consistent with the rotor having been driven by the engine at impact.

1.2.7 The pilot's cyclic stick was broken off at its base, but control continuity and correct operating sense were established as far as the non-rotating swash plate. Above the rotating swash plate, linkages were damaged by impact forces. The adjustable cyclic stick friction knob was not tight.

1.2.8 The collective lever was broken just below the throttle twist grip, but control continuity was established. The correct operating sense could not be confirmed because of impact damage to the pitch linkages. The adjustable collective lever friction knob was not tight. The throttle pointer on the fuel control unit was consistent with the twist grip throttle having been fully open.

1.2.9 Dual pedals for tail rotor control were fitted, but on the right side they were secured out of reach of passengers' feet. Control continuity was established as far as the break in the tail boom. The tail rotor drive shaft was broken in tension where it exited the air intake box, and there was a slight kink in the remaining length of shaft from aft of the break to the tail rotor. All of the tail rotor assembly was recovered. One tail rotor pitch control link was bent, but the tail rotor blades were only slightly damaged.

1.2.10 The tail boom had broken off downwards and to the right, removing the right engine access door in the process. A small section of the forward left side of the tail boom was not recovered.

1.2.11 The upper vertical stabiliser had tip damage consistent with its having hit the water while moving to the left and then striking the angled stabiliser, and also some short scratches from brief tail rotor rotational impact. The lower vertical fin was almost undamaged.

1.2.12 The underside of the fuselage had almost no impact damage. Damage to the landing gear and windscreen frames indicated that they had impacted the water while the helicopter was in a slight left nose-down attitude.

1.2.13 The engine mounts were intact. The air intake was choked with rock and the accessories gearbox had damage from the impact and immersion.

1.2.14 The left front door, the flight manual and daily flight record, some survey equipment and radios were not recovered. The scientists' packs and other personal items were destroyed as a result of having been immersed.

1.2.15 The instrument console was restrained by cabling only. The following readings were obtained:

Parameter	Reading		Parameter	Reading
Airspeed indicator	needle broken		Altimeter subscale	1023 hectoPascal[10]
N2 and rotor RPM	0		Vertical speed indicator	1100 ft per minute up
turbine outlet temperature	100°C		Torque	102 pounds per square inch
N1	0.5%		[not used]	
Generator – ON	Battery – ON		Start pump – OFF	Auto re-ignition – ON

1.3 Meteorological information

1.3.1 On 11 December 2006, according to a MetService[11] analysis, the North Island was under a large, slow-moving ridge of high pressure that brought mainly clear skies to the Central Plateau area. At 1700 and 1800, an automatic weather station at Waiouru aerodrome, 20 kilometres south of the crater and at an elevation of 2686 feet, recorded the air temperature as +17°C and the air pressure as 1022 hectoPascals.

1.3.2 The pilot said that while flying the weed control task on the northern slopes of the park, the weather had been fine with a southerly breeze, but some DOC staff said they had been "knocked around a bit" by the wind. The pilot did not recall what the wind direction or strength had been while he was flying up the mountain.

1.3.3 Both the pilot and ranger A said that the conditions were near perfect when they took off from the lake outlet. They described the wind as a northerly of 10 knots, or a very light north-easterly breeze, respectively. The scientist noted wisps of thin cloud moving from the east or south-east past the summit. He said the air temperature was about +2 to +4°C. The pilot did not recall the air temperature at the lake.

1.3.4 MetService estimated that at 1730, the wind at the summit of Ruapehu, 9175 ft above sea level, was southerly at 35 knots and the air temperature was about +3°C. MetService estimated that the temperature of the plume of warm air above the lake surface was between +4°C and +22°C. Mixing of the overlying airflow and the plume would result in an unpredictable and variable temperature gradient within the crater basin. The density altitude[12] within the plume was estimated by MetService to have been in the range of 10 390-11 490 ft for plume temperatures of between +10°C and +20°C.

1.3.5 A helicopter pilot who later assisted with the rescue had been operating earlier in the day at a ski field on the south side of Mount Ruapehu. He said that the south-westerly wind had been gale force[13] late in the morning, but the speed decreased later in the day and it was a light southerly during the rescue. He said that, in his experience, the wind at the top of the mountain on any day could shift 4 directions in 4 minutes.

1.3.6 Pilots for a scenic flight operation based at the Chateau aerodrome north of the park said that they cancelled flying at 1500 because conditions around the summit of Mount Ruapehu were

[10] A hectoPascal is 100 Pascal, Pascal being the international unit of pressure.
[11] MetService is the national provider of weather information.
[12] Density altitude is pressure altitude corrected for non-standard temperature.
[13] Gale force is a wind speed in the range of 30-50 knots.

too rough. They estimated that the wind at 9000 ft had been 30 knots from the south and south-west for most of the day.

1.4 Personnel information

1.4.1 The pilot began flying training in 1996 and obtained his commercial pilot licence (helicopter) in March 1997 and a Hughes 500C rating in October 1997[14]. He held an agricultural rating and a D category instructor rating. He had been employed as a pilot by the operator since August 1999, and had been Chief Pilot since 2001.

1.4.2 The training for the pilot's commercial licence had been conducted in the central North Island region and his pilot logbook contained certification that the mountainous terrain training requirements in force at the time had been met. An outline of those requirements is shown in Appendix A. Much of the pilot's commercial helicopter flying had been at elevations below 4000 ft, and although perhaps half of his recent flying before the accident had been around Mount Ruapehu, he had not had any mountain flying training specific to his employment.

1.4.3 The pilot said he had operated from Dome Shelter before, and at the outlet, although never with 5 people on board. He said he had hovered out-of-ground-effect in the Crater Lake area before and flown around Mount Ruapehu in the Hughes 500C many times with 5 persons on board and had never experienced any performance problems. He also described having landed at 6000 ft in nearby mountain ranges in summer, which he thought could have been density altitudes of 7000-8000 ft. However, he also said that he had not given proper consideration to the demands of operating at 8500 ft. He said he was aware of how the wind can vary around a mountain but he could have underestimated the wind behaviour on this flight.

1.4.4 The pilot said he was fit for flying, rested and in good health on 11 December 2007. He had not flown on the previous 2 days and flew about 6 hours on the day of the accident. That work rate was within the operator's flight and duty time limits. The pilot's total and recent experience, as at 11 December 2006, were as follows:

Licence	commercial pilot licence (helicopter)
Aircraft type ratings	Eurocopter AS350, Bell 206, Hughes 269 and 369C, Robinson R22 and R44
Medical certificate	Class 1, valid to 22 March 2007
Last competency check	1 May 2006
Last biennial flight review	1 May 2006
Flying experience	2735 flight hours total, 625 flight hours on type
Duty time	9.25 hours
Time since end of last duty	63 hours
Flying last 7 days	11 hours
Flying last 90 days	94 hours, 61 hours on type

1.4.5 The crewman was 38 years old. He held a commercial pilot licence (helicopter) with about 180 hours' total time on Robinson helicopters only. He had been employed by the operator for one week for ground and crewman duties, with a view to employment as a pilot.

[14] The H369C type rating included the H369HS model.

1.5 Helicopter information

1.5.1 The Kawasaki-Hughes 369HS helicopter, a version of the Hughes H369C helicopter, was built by Kawasaki Aerospace in Japan under licence from Hughes Helicopters of the United States. Both versions are commonly referred to as the Hughes 500C[15].

1.5.2 ZK-HDJ was manufactured in 1977 and had accumulated 6730 flight hours before being imported into New Zealand in October 2000. The operator took possession of the helicopter in July 2002.

1.5.3 The engine fitted to ZK-HDJ was a Rolls-Royce (Allison) 250-C20B gas turbine engine, serial number CAE-832828, manufactured in 1980 and installed on 21 October 2005, at which time it had accumulated 9877 hours' total time. An optional engine air particle separator, which would have reduced the hover performance, was not installed.

1.5.4 According to its logbooks, ZK-HDJ had been maintained in accordance with the operator's approved maintenance programme. The annual review of airworthiness was next due on 26 September 2007.

1.5.5 Civil Aviation Rule 43.153, Review requirements, states, in part:

> (a)… a person performing an annual review of airworthiness for an aircraft must … (4) check that since the last annual review of airworthiness or inspection for the issue of an airworthiness certificate— …
> (vi) the recorded weight and balance data reflects any changes to the aircraft's weight and balance and that the recorded weight and balance data is within the published weight and balance limitations for the aircraft; and
> (vii) the flight manual, including every applicable supplement is the current version for the aircraft in its existing state; and
> (5) check that the overhaul and finite life of each lifed component is recorded and is within the limits laid down in the applicable manufacturer's document …

1.5.6 A maintenance log entry was made on 14 December 2005 after a pilot reported that the engine speed drooped when power was quickly applied. The cause was found to be dirt within the air control circuit[16].

1.5.7 The engine turbine was overhauled in April 2006 and the first and second stage turbine wheels replaced at that time. The compressor bleed valve was replaced in the same month.

1.5.8 On 2 November 2006, at 8772 airframe hours, a combined 100-, 300- and 600-hour inspection of the airframe and engine, which included a performance check of the engine, were completed. The helicopter was then flown for 53 hours and, at the time of the accident, had accumulated 8825 flight hours', and the engine 10 208 hours', total time since new.

1.5.9 The engine-driven fuel pump, serial number PE5129, was fitted when the engine was installed into ZK-HDJ. The pump had an overhaul interval of 2250 hours and according to the engine logbook was due for removal at 10 195 engine hours, 13 hours before the accident. No extension to the overhaul interval was permitted, and the cause of oversight was not determined. An engine would not achieve full power if the fuel flow or pressure was below specification.

1.5.10 The most recent maintenance was a 24-month avionics inspection carried out on 24 November 2006. That included the annual inspection of the emergency locator transmitter, whose signal output had been checked as satisfactory on 2 November 2006. The transmitter batteries were due for replacement in March 2009.

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[15] Ownership of the helicopter type certificate had moved to McDonnell Douglas Helicopter Systems, which was, at the time of the accident, a division of the Boeing Company.
[16] Engine speed and power output were regulated, in part, by air pressure bled from the engine compressor.

Weight and balance

1.5.11 The empty weight of a helicopter included, in addition to unusable fuel and trapped fluids, any items of equipment listed on the Weight and Balance Report, form CAA2102.

1.5.12 ZK-HDJ was last weighed on 16 May 2003. The equipment list at that weighing comprised a first aid kit, crash axe and fire extinguisher. The form CAA2102 recorded the helicopter's empty weight and centre of gravity position as:

weight (lb)	arm (inches)	moment (lb-inches)
1426.2	106.2	151 539.3

1.5.13 That data was included as the empty weight in a computer programme the operator used to calculate the operating weight and balance of ZK-HDJ when it was flown on air transport operations from the operator's base. For each flight, the weight and location of other equipment on board had to be allowed for when calculating the total weight[17].

1.5.14 In addition to the equipment listed as part of the empty weight, the operator typically had on board the helicopter 2 or more head sets, additional survival gear and the flight manual. Previous versions of form CAA2102 for ZK-HDJ had varied in whether the dual flight controls, the flight manual or head sets were included in the equipment list. A cargo hook and dual tail rotor pedals were installed at the time of the accident, items that the pilot and the maintenance contractor said were part of the empty weight. They were not listed on the most recent form CAA2102, although maintenance log entries showed that the cargo hook was probably installed when the helicopter was weighed on 16 May 2003. The pilot thought that the aft cabin steps were also part of the empty weight.

1.5.15 The helicopter log book Summary of Empty Weight Changes had one entry since the last weighing: a change of battery type on 29 November 2004, which resulted in a 15.4-lb weight decrease and a revised empty weight and centre of gravity position as follows:

weight (lb)	arm (inches)	moment (lb-inches)
1410.8	106.8	150 692.3

1.5.16 In June 2003, removable aft cabin steps that weighed 17 lb each were installed in accordance with an approved modification. The associated flight manual supplement stated, in part:

> … unless the rotorcraft equipment list indicates that [the modification] was installed at the last weighing this data must be taken into account when determining the weight and balance of the loaded rotorcraft.

1.5.17 The flight manual supplement for the aft cabin steps stated, in part:

> … aft cabin steps are for boarding and alighting [from] the rotorcraft while it is on the ground … passenger use of the steps, while in flight, is prohibited.

1.5.18 After the accident, the pilot prepared a weight and balance spreadsheet using the operator's programme that showed the take-off weight on the accident flight was 2494 lb, with the longitudinal centre of gravity at 98.2 inches rearwards of the datum[18]. The allowable range for weights over 2400 lb was 99 to 104 inches rearwards of datum. The pilot had reduced the basic weight by 32 lb to allow for the rear seats being removed, but he had not added the weight of the protective plywood flooring or other equipment, which he said had also been part of the empty weight when the helicopter was last weighed. The total passenger weight used was 50 lb less than the total declared by the passengers.

1.5.19 The maximum allowable gross weight with an internal load for ZK-HDJ was 2550 lb.

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[17] Advisory Circular 43-2, "Aircraft weight and balance control", CAA, 25 December 1997.
[18] A datum is a reference line or point from which measurements are made.

1.5.20 Civil Aviation Rules required operators who used declared (rather than actual or standard) passenger weights to add 9 lb for each passenger. Using the revised empty weight and centre of gravity from 29 November 2004, the declared weights only of the pilot and the passengers, the estimated weight of the survey team's packs and adding the weight of the aft cabin steps, the Commission calculated that the take-off weight from Crater Lake was 2590 lb. The calculated centre of gravity was within the longitudinal and lateral limits.

Helicopter performance

1.5.21 The performance of a helicopter is based primarily on its ability to hover, which is the most critical power requirement. The major factors that affect performance are power available, density altitude, weight and wind. As density altitude increases, the power available decreases, and therefore the margin between power available and required decreases. At the "hover ceiling", the power required equals the power available. Charts are provided for the hover ceiling under various conditions of weight, altitude and air temperature. The factors that affect hover performance have a similar effect on climb performance.

1.5.22 Pilots are taught to calculate the expected performance by reference to data graphs found in the flight manual for the specific helicopter, and then to confirm the expected figures by performing a power margin check under the ambient conditions at the point of intended operation, for example, prior to landing or in the hover before taking off.

1.5.23 In practice, apart from the initial take-off and landing at a location, an experienced pilot might omit a deliberate power check on every take-off and landing if the conditions were familiar or unchanging, such as at the base location or on a repetitive job with planned weights. With experience, the helicopter's capability would be well known or predicted by a rule-of-thumb. Rules-of-thumb were not normally used when operating aircraft close to their limits.

1.5.24 The pilot said his rule-of-thumb for determining whether a load was acceptable was: if he could hover in-ground-effect and then accelerate through translational lift, he would be able to climb ZK-HDJ up to 20 000 ft. He said that a margin of 10 pounds per square inch of engine torque while in a hover would be adequate to perform a vertical take-off.

1.5.25 The approved flight manual noted that compliance with the operating limitations was mandatory, but the published performance data and procedures were recommended only. Data was included to calculate both the in-ground-effect and the out-of-ground-effect hover ceilings.

1.5.26 The combination of ambient temperature and altitude during the take-off from Crater Lake put the helicopter above the "engine critical altitude" line depicted on the hover performance charts. This meant that the engine power was limited by the maximum turbine outlet temperature of 793^{o}C rather than the torque pressure limit of 64.5 pounds per square inch.

1.5.27 The MetService estimates of density altitude and temperature ranges, given in section 1.3, were used to estimate the hover ceiling of ZK-HDJ near Crater Lake. For an in-ground-effect hover, the engine was limited by temperature and not torque, and the hover weight capability was in excess of 2600 lb. The out-of-ground-effect maximum hover weight was 2506 lb at 8000 ft pressure altitude and a temperature of +4^{o}C, the approximate conditions at the take-off point, but would reduce to 2450 lb over the lake with an assumed temperature of +15^{o}C, conditions that would result in a density altitude of nearly 11 000 ft.

1.6 Survival aspects

1.6.1 Civil Aviation Rule 91.207, Occupation of seats and wearing of restraints, required the pilot to ensure that each passenger occupied a seat or berth and to fasten their safety belt or restraining belt during each take-off and landing and when the aircraft was flying at a height of less than 1000 feet above the surface. The operator's operations manual repeated this requirement.

1.6.2 Prior to commencing the weed task, the pilot gave the involved staff a safety briefing that included the use of seat belts and karabiners. He said that the nature of the weed task meant he could not check that everyone was wearing a seat belt on each short flight. The pilot also said that there was "a local culture" not to wear any restraint. The crewman said that for most of the time during the weed task, neither he nor the passengers were restrained.

1.6.3 When the accident occurred, the pilot was the only person wearing any restraint. The crewman recalled hitting the ceiling and the floor during the impact. The 3 DOC staff said they thought that not having their seat belts secured at impact was a factor in their surviving the accident and escaping from the helicopter. They each expressed a fear that they could have been trapped in the partly submerged wreckage.

1.6.4 The Commission found no published data regarding the severity of injuries received by persons ejected from aircraft during accidents. However, road safety research[19] had concluded that one in 5 occupants thrown from a car received fatal injuries. A motorist who used a seat belt would probably not be thrown from the car after the impact. The rate of fatal injury for ejected occupants was about 40 times that for occupants not thrown from their cars. There was no evidence that wearing a seat belt increased the fatality risk from a vehicle fire or submersion.

1.6.5 Crash survivability considerations in the design of aircraft, including helicopters, were based on the aircraft structure absorbing as much energy as possible during the impact and the structure maintaining a protective shell around the occupants. The seat structure and restraint system were designed to retain the occupants inside the protective shell and to absorb additional energy so that the deceleration of the occupants was reduced to a tolerable level[20]. The Commission heard anecdotes of commercial helicopter operations by operators elsewhere in which passengers were carried without the correct number of seats installed. The practice was more likely when there was a series of flights involving mixed loads of passengers and cargo.

1.6.6 The United States Army, which has conducted the most extensive studies of aircraft crash survivability, noted that[21]:

> Adequate restraint in a crash can mean the difference between life and death, since evacuation from a burning or sinking aircraft is considerably improved if no prior injury or debilitation has occurred.

1.6.7 Most of the terrain around Crater Lake was unfavourable for a forced landing, but the lake offered the alternative of a controlled ditching. The operator was one of a number who flew within or over Crater Lake basin without life jackets being carried on board. Civil Aviation Rule 91.525, Flights over water, stated at the time, in part:

> (a) An aircraft operated on over water flights must be equipped with –
>
> (1) for single-engine aircraft … on flights more than gliding distance from shore, one life preserver for each person on board stowed in a position readily accessible from each seat or berth; …

1.6.8 Civil Aviation Rule 91.525 was amended in 2007 and the relevant clause then stated, in part:

> (a) An aircraft that is operated on a flight over water must be equipped with 1 life preserver for each person on board and stowed in a position that is readily accessible from the seat or berth occupied by the person if –
>
> (1) the aircraft is a single-engine aircraft and the flight distance to shore is more than gliding distance for the aircraft;…

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[19] "Safety Belt Use, Ejection and Entrapment", O'Day, J and Scott, R E, *Health Education and Behaviour*, Vol. 11, No. 2, 141-146, 1984.
[20] *United States Army Aviation Systems Command, Aircraft Crash Survival Design Guide, Volume IV – Aircraft Seats, Restraints, Litters and Cockpit/Cabin Delethalisation*, page 4, 1989.
[21] ibid, page 114.

1.6.9 Although the lake was warm, the highly acidic water was dangerous to a person's health. All of the occupants had been submerged to some degree and became hypothermic in the cold air. The over-hanging ice cliff and falling rocks presented further dangers to the survivors.

1.6.10 The operator had recognised the risk of hypothermia to passengers on its scenic flights should a helicopter be forced to land high on the mountain, and recommended that they wear sturdy footwear and a light jacket. The pilot was wearing a helmet, warm clothing and work boots, but no gloves.

1.6.11 The group shared spare alpine clothing from the survey team's packs and attended to those who were worst affected by cold and injury. Both first aid kits from ZK-HDJ were used. Fittings and equipment from the wreckage were used to improvise shelter. The pilot said emergency blankets were carried for 5 people, but some passengers said they did not know what survival equipment was carried. Three unwrapped survival blankets were recovered from the wreckage.

1.6.12 The pilot removed the emergency locator transmitter antenna from its cockpit stowage and fitted an alternative short antenna that should have radiated a useful signal. However, the National Rescue Coordination Centre said that no emergency signal was received at the relevant time. The pilot left the transmitter behind when he was rescued, and it was not found again.

1.6.13 Conventional advice was against removing an emergency locator transmitter from an accident scene, unless the survivors stayed together, because rescue efforts were focused on finding the transmitter location.

1.6.14 The scientist's persistence in finding a serviceable radio backed up the pilot's trek for help. The DOC Duty Officer knew that the survey party that was to have returned by helicopter had not reported back at base, and had already commenced enquiries to establish the party's location.

1.6.15 The operator's flight-following[22] procedure for commercial transport operations was based on the pilot concerned making an arrangement with a party, such as the operating base or a family member. For air transport operations, the operator used the national flight planning system.

1.7 Organisational information

The operator

1.7.1 The operator purchased the business in 2000 and was certificated for helicopter air transport and commercial transport operations under daytime visual flight rules. On 11 December 2006, the fleet consisted of ZK-HDJ and a Bell 206L helicopter.

1.7.2 The pilot was the Chief Pilot and Operations Manager. Another full-time pilot and 3 relief pilots were employed. The annual flight crew competency check and biennial flight review required for each pilot by the Civil Aviation Rules were contracted to an independent helicopter training organisation.

1.7.3 In October 2006, the operator entered a contract to provide DOC with unspecified helicopter services for one year. Support of the weed control programme came under that contract. The request to uplift the survey team was the first time that DOC had asked the pilot to operate on the upper mountain.

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[22] Flight following is a procedure for obtaining periodic position or status reports from an aircraft and for initiating a search for the aircraft if a scheduled report is overdue, usually by more than 30 minutes.

1.7.4 The operator's operations manual reflected the requirements of Civil Aviation Rule 135.303, Goods, passenger and baggage weights. The relevant section of the manual stated, in part:

> When operating Commercial Transport Operations from a remote aerodrome where it is not possible to establish actual weights of goods or baggage, the pilot must assess the weight of each item by lifting it briefly off the ground. If the estimated total weight of all items exceeds the amount that can be carried, items shall be off-loaded until the pilot is satisfied that the maximum certificated all-up weight of the aircraft will not be exceeded. It is permissible to use indicative goods and baggage weights for items typically carried, e.g., trampers packs, see Appendix page 14B.

1.7.5 Appendix page 14B of the operations manual did not list any indicative weights.

1.7.6 The Emergency and Survival Equipment List in the operations manual did not include the additional survival items carried, such as emergency blankets and an additional first aid kit.

1.7.7 The Civil Aviation Authority (CAA), as part of a safety audit conducted in February 2006, assessed the operator to have a "high" rating of non-compliance, a rating based in part on CAA findings and notified incidents over the previous year. The CAA had since recorded that the operator took appropriate corrective actions.

The regulator

1.7.8 The need for a pilot to refer to documented performance data before flight was implicit in Civil Aviation Rule 135.57, Flight preparation and flight planning, which states, in part:

> (a) The holder of an air operator certificate must ensure that for each air operation … appropriate information is available to the pilot-in-command to complete the preparation for the intended operation.

1.7.9 Civil Aviation Rule Part 135 sub-part D dealt with aeroplane performance only and had no rules for helicopter performance. The Rule had been modelled on the related United States Federal Aviation Rule, which did not include helicopter performance at that time. The Rule part had been reviewed and amended several times since its inception in 1995, but the performance requirements in sub-part D had not been reviewed. CAA helicopter specialists were of the opinion that helicopter flight manuals adequately addressed performance requirements.

1.7.10 The specific performance data provided by helicopter manufacturers was supplemented by general information in the booklets "Helicopter Performance"[23] and "Mountain Flying" published by the CAA. Extracts from "Helicopter Performance" are included in Appendix B.

1.7.11 The CAA has estimated that around 20% of all helicopter accidents in New Zealand have been performance-related. In the introduction to "Helicopter Performance", the CAA wrote:

> Approximately 60 percent of these accidents occurred during the take-off or landing phases of flight … Many of these accidents happened when the helicopter was being operated from sites that were elevated, facing out of wind, restricted by terrain, sloping, or had a rough surface. In most cases the sites were on ridge tops or in confined, steep-sided valleys. Often the helicopter was being operated at a high gross weight, in high temperatures and low air pressures.
>
> Many, if not all, of these accidents could have been avoided if the pilots had been fully aware of the prevailing conditions and taken the time to determine the performance capabilities of their machine before committing themselves.

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[23] "Helicopter Performance", *Good Aviation Practice series*, Civil Aviation Authority, November 2002.

1.7.12 The pilot, as the operator's Chief Pilot, had to ensure that his self-assigned tasks complied with Civil Aviation Rule 135.503, Assignment of flight crew duties, which reads, in part:

> (a) A holder of an air operator certificate must ensure that every person assigned as a flight crew member on an air operation conducted under the authority of the certificate— …
>
> (3) meets all the experience, training, and competency requirements for the task assigned; and
>
> (4) meets all route and aerodrome qualification requirements for the intended operation.

1.7.13 The pilot was also required under Civil Aviation Rule 135.561, Recurrent training for crew members, to ensure that he and the operator's other pilots were proficient and current in each type of operation they performed.

Department of Conservation

1.7.14 DOC managed its field operations through Conservators of "regions", each of which could contain a number of "areas". The Ruapehu Area Office managed that part of Tongariro National Park that contained Mount Ruapehu, the weed control site and the accident site.

1.7.15 DOC advised that they preferred to use operators equipped with helicopters more powerful than the Hughes 500C when working on Mount Ruapehu, but the Ruapehu Area Office hazard management plan did not specify helicopter capability, nor pilot experience and competence.

1.7.16 The DOC supervisory staff could influence the choice of helicopter operator for a particular task, but would not interfere in a pilot's conduct of a task. The supervisor of the weed job said that she had no reservations about using the pilot to uplift the survey team from the mountain.

1.7.17 A document, "Working Around helicopters, General Instructions for Staff", issued by DOC in July 1999, was current on 11 December 2006. Among the instructions were the following:

> Fasten your seat belt on entering a helicopter. Keep it fastened until the pilot signals you to get out.

and

> When flying into the back country, staff must be equipped to spend the night out even if the intention is not to do so. Clothing must be practical for the circumstances...

1.7.18 The reasons for the above instruction regarding seat belts was clearly not well understood within DOC. An internal debriefing following the accident recorded that "[seat belts] should be worn when available and time allowed".

1.7.19 DOC investigated its involvement in the accident and found[24], in part, that there had been:

- deficiencies in some [DOC] operating procedures and compliance with those procedures and emergency planning
- unclear communications between various DOC staff and the pilot [that] created incorrect assumptions about the nature of the task
- inadequate risk assessment and hazard management procedures [related to the helicopter contract].

[24] Final Report, "Serious Harm Work Related Incident, Mount Ruapehu Crater Lake Helicopter Crash", Department of Conservation, 1 March 2007.

1.7.20 The DOC report made recommendations related to the minimum equipment and competency standards for helicopter operations in the Mount Ruapehu crater, the inclusion of detailed health and safety plans in aircraft hire contracts, reinforcement of the established DOC requirements for passengers to wear seat belts and for persons operating in alpine conditions to have proper personal equipment and clothing.

1.8 Additional information

Mountain flying

1.8.1 Flying in mountainous terrain places additional demands on a pilot and helicopter performance for many reasons, including the following:

- increased density altitude results in decreased helicopter performance
- the absence of a horizon can make flight path control more difficult
- wind speed usually increases with altitude, and its direction can be highly variable
- terrain (and wind) can restrict flight path and landing options.

1.8.2 Authoritative advice on flight in mountainous terrain[25] often included considerations such as the following:

- before take-off for a mountain landing site, determine the density altitude at the site, the maximum weights for hover in-ground-effect and out-of-ground-effect, and the maximum engine power available
- carry the minimum possible weight, into and out of the site, for the task
- on arrival in the area of intended landing, perform a full power check at or above the level of the site
- check the wind direction by over-flight of the site in at least 2 directions
- maintain a constant awareness of the wind speed and direction
- before departing a mountain site, an adequate power margin in the hover is essential
- the ability to trade altitude for airspeed can provide an escape route
- translational lift occurs at a higher ground speed than at sea level, and acceleration will be slower
- if obstacles are present ahead of or above the intended take-off path, thorough planning is required, and the maximum space used to accelerate the helicopter to a safe climb speed
- if effective translational lift or an adequate climb angle is not achieved, the pilot must be able to safely discontinue the take-off.

[25] For example, *Flight Safety Australia* magazine, Civil Aviation Safety Authority, Canberra, March-April 2000.

1.8.3 On 1 August 2008, the CAA extended the standards for theoretical and practical training in mountain flying to be met before the issue of a commercial pilot licence (helicopter). The amendment to advisory circular AC61-5 noted, in part:

> Helicopter basic mountain flying training is intended only as an introduction to mountainous terrain operations for commercial helicopter pilots or experienced private helicopter pilots.
>
> More extensive mountain flying requires a higher level of knowledge, skill and experience and so requires additional theory and practical training before it can be conducted safely. Therefore, a person holding a commercial helicopter pilot licence issued after 31 August 2008 should not conduct advanced operations in mountainous terrain, including landing at, or making an approach to, any point above the height at which competence has been demonstrated without first completing further training.

1.8.4 The CAA advised that further guidance on advanced training, which encompassed role-specific training by an operator, would be included in an amendment to Advisory Circular 119-3 that was scheduled for publication by the end of 2008.

2 Analysis

2.1 The flights carried out with ZK-HDJ on 11 December 2006 comprised 2 distinct tasks: one that was planned for, and one that was not. During the weed-clearing work on the lower slopes of the park, the performance demands were within the helicopter's limits, the pilot had no concern for the operation of the helicopter, and the task was completed without incident, although the wind was blustery.

2.2 The removal of the rear seats was probably not permitted and there was frequent non-compliance with the seat belt rule, which became a safety factor in the accident later. Although use of the aft cabin steps expedited boarding and alighting while the helicopter was hovering, the flight manual prohibited their use in flight.

2.3 Non-compliances such as these increased the risk to passengers on helicopter operations, but were unlikely to be discovered until after an accident. The CAA's planned audit programme was notified in advance to operators and was therefore unlikely to provide the CAA with a completely true picture of industry standards and compliance. A safety recommendation was made to the Director of Civil Aviation regarding the effectiveness of the audit and surveillance programme.

2.4 The second task, to pick up the survey team from the mountain and return them to the park headquarters, appeared to the pilot to be a simple flight. However, the combination of high altitude, heavy weight and the pilot's relative inexperience in the Crater Lake basin meant that it was a complex task that proved to be beyond his experience and beyond the ability of the helicopter. These points are elaborated below.

2.5 The DOC internal report on the accident concluded that DOC had inadequate contractual checks to ensure the suitability of operators, pilots and helicopters when working on Mount Ruapehu. However, Civil Aviation Rules placed similar obligations on operators and pilots for similar reasons. The public had a right to expect that a licensed pilot and a certificated operator would not offer a service unless they had the relevant training, experience and capability to complete it safely.

Lack of planning for the mountain task

2.6 DOC had accepted the operator's assessment of the risk of flight operations, but had not specifically assessed its own risks associated with the weed flights. The flight to Crater Lake was an unplanned task, for both DOC and the pilot, and it was offered, accepted and flown without any planning or risk assessment. If the pilot had considered the flight as a separate task rather than as an add-on to the transit flight home, he might have identified the changing requirements and made appropriate decisions to eliminate or reduce the risks.

2.7 Whether the pilot was already fatigued before he accepted the mountain task could not be determined. He had been working for about 6 hours on the weed task, but he had kept hydrated and taken an extended lunch break, and he had not flown on the previous 2 days.

2.8 Although the pilot initially mistook the mountain task to be the pick-up of only one person from the Dome Shelter area, he did not follow the recommended practice of minimising the total weight for a flight into mountainous terrain. The helicopter weight was the only performance variable that the pilot could directly control. The crewman and ranger B were not required for the task and were unnecessary weight. For the same reason, because he knew of the mountain task before refuelling after the weed task, the pilot should have loaded enough fuel only for the mountain task plus the required reserve. Had the pilot taken the minimum possible weight, he would not have had a problem when he found that there was an additional person to be uplifted. After the mountain task, the pilot could have loaded more fuel for the ferry flight to Taupo and taken the crewman on that flight.

2.9 The DOC field supervisor was an experienced mountaineer, so it was surprising that she allowed ranger B to go on the flight without clothing and equipment for alpine conditions. The pilot also did not recognise that the light clothing of ranger B and the crewman might compromise their personal safety in the event of an accident. Their inadequate dress and equipment became critical issues after they were forced into a survival situation, which was why DOC had published clothing and equipment instructions for its staff.

2.10 During the flight up the mountain, the pilot had an opportunity to determine the general wind flow, but he either did not take that opportunity or misjudged the wind. The certainty that the wind within the lake basin would be variable did not register with him.

2.11 A pilot more experienced in mountain flying, seeing that the planned load and location had altered and that the task was now more demanding in the prevailing conditions, would probably have reassessed the intended operation and ensured that no unnecessary weight was on board.

2.12 The pilot had a number of opportunities to calculate the expected performance on the mountain, even as the scope of the task shifted. His response to ranger A asking later how the increased load would be managed could have been due to the pilot wanting to appear as capable as the more experienced pilots DOC normally used for Crater Lake flights; but those pilots had more powerful helicopters and did not take 4 passengers and their gear from that site. Ranger A deferred to the pilot's judgement, as a passenger without relevant pilot experience or operational control of a task might do.

2.13 The pilot's decision to take everyone and "give it a go" might have been acceptable if he had an accurate estimate of the weight and if an earlier review of the charted performance had shown that the take-off and an out-of-ground-effect hover were possible. However, he had not reviewed the charts for this task and had made a cursory visual assessment only of the weight of the passengers.

2.14 The pilot had performed a full power check before landing at the outlet and had estimated that the all-up weight did not exceed the maximum permitted, but otherwise his planning and execution of the flight met few of the recommended practices described in paragraph 1.8.2. His primary indicator of performance was to be the in-ground-effect hover power check only, but conventional advice was that performance planning for mountain flying should be based on the more conservative out-of-ground-effect data. That data could not be referred to easily while flying, so would have to be obtained during prior planning. When operating at the margins of performance, a rule-of-thumb power check alone could be misleading.

Pilot's knowledge and experience

2.15 The pilot had logged over 2700 total flight hours and more than 600 hours on the Hughes 500, but he was inexperienced in the type of mountain flying he was attempting to do that day. Although he had been the operator's Chief Pilot since 2001, the expansion of his operational knowledge and experience had not been closely supervised. Annual competency checks for him and the operator's other pilots were necessarily limited in scope compared with the range of tasks that a pilot could meet in the course of a full year.

2.16 The pilot's holding of a commercial pilot licence certified that he had acquired the basic knowledge and demonstrated the basic helicopter flying skills necessary for him to operate safely in mountainous terrain. However, a key skill for pilots, partly developed through experience, is the ability to critically evaluate the operational factors of each task and to acknowledge, when necessary, that one or more factors is beyond the pilot's ability or the capability of the helicopter.

2.17 The pilot demonstrated a limited understanding of the operational considerations of mountain flying and the effect of altitude on the performance of the helicopter. This was evident in his comparison of scenic flights around the summit of Mount Ruapehu with landing and taking off high on the mountain, and his equating the helicopter performance on the weed task with the expected performance when carrying a similar load more than 5000 ft higher up the mountain.

2.18 Increased risk can arise if a pilot tries to exploit a helicopter's operational flexibility on a task that is outside the pilot's training or recent experience. In his role of Chief Pilot for the operator, the pilot was responsible for supervising pilot employees and assigning them flying tasks on the basis of their training, competency and current experience. Similarly, he needed to assess that he, too, could safely perform a task before accepting it for himself.

2.19 Commercial transport operations often challenge the means of compliance with Civil Aviation Rule, because operations to remote places lack the support and facilities found at a base location. Helicopter operations are more commercially successful when they can take full advantage of the machine's operational flexibility. However, because direct supervision was often absent or not even contactable for advice, a pilot-in-command has to make decisions on the spot. Sound decision making, which might include declining a task, requires appropriate experience and training.

2.20 The level of operational experience needed by the Chief Pilot of a small company has been a difficult question for the CAA and industry to resolve. Public safety expectations were important, but unrealistic controls on entry to the civil aviation system could discourage keen, competent but less experienced participants, some of whom would be required for the continuation of the industry. The CAA understood the supervision issue, which had been partly addressed in 2005 when the relevant experience requirement for Chief Pilot applicants was raised. The CAA could also approve an applicant subject to specified operational limitations or requirements, such as a period of supervision or the applicant's prior attendance on a CAA course for Senior Persons Responsible for Air Operations, that is, Chief Pilots.

2.21 The CAA had extended the mountain flying training to be completed before the issue of a private or commercial helicopter licence and was preparing Rule changes that would clarify an operator's obligation to ensure its pilots were trained for the roles offered by the operator. The CAA also encouraged less-experienced chief pilots to adopt a pilot categorisation scheme, a simple system that provided visibility of each pilot's operational approvals. However, the Commission remained concerned that helicopter pilots have the knowledge, experience and currency necessary for intended operations, and that their supervision was adequate. A safety recommendation was made to the Director of Civil Aviation that he address this safety issue.

Take-off from the mountain

2.22 Commercial pilots are trained to appreciate that strong winds in mountainous terrain can be unpredictable. The wind speed and direction above the highest terrain in an area might accurately reflect that shown on a weather chart, but is unlikely to be the same as that found below the tops. Safe flying in mountains requires thorough training, experience and close attention to the wind.

2.23 The mountain had been affected by a strong south-west flow that as late as 1500 was strong enough to force the locally based scenic flight operator to cancel flying. The observations of the wind by other pilots were consistent and suggested that the northerly wind at the outlet was a local effect caused by deflection off the ice cliffs and slopes opposite.

2.24 If the pilot had correctly assessed the overlying wind while flying up to Crater Lake, he did not subsequently apply that knowledge. Instead, he relied on the localised wind that was reported by ranger A, and seen by himself on the lake surface, being steady and he approached the landing site directly without further evaluation of the wind patterns. The approach and landing were uneventful, but the pilot's technique indicated a lack of familiarity with and respect for the changeability of the wind in mountainous terrain.

2.25 If the pilot had any doubt about the capability of the helicopter to perform the take-off with everyone on board, especially after being indirectly challenged by ranger A, he could have reduced the load at any time up until the scientist had re-boarded the helicopter. The "shuttle" option would have meant leaving the 2 poorly clothed passengers waiting in cold conditions, but it was unlikely that the pilot considered that option or the consequence. Even so, he could have taken them to the park headquarters first and then returned to retrieve the survey party.

2.26 According to the pilot, the hover check was conducted into a light wind and indicated to him that there was sufficient power to allow the helicopter to climb. The flight manual data showed that a hover could be achieved in-ground-effect, but not out-of-ground-effect, at that weight.

2.27 The pilot's expectation that the power requirement would reduce by remaining in-ground-effect as he accelerated the helicopter up an adjacent slope was misplaced. If the northerly wind had persisted, he might have expected updraughts initially, but once the helicopter was accelerated, more power was initially required. The benefit of ground effect was lost over sloping ground. Very soon after take-off, the helicopter would have become exposed to the south-westerly wind and downdraughts within the crater basin. Although the pilot was able to maintain airspeed, there was then insufficient power available for the helicopter to climb.

2.28 The pilot said that he thought the performance would be torque-limited, whereas reference to the flight manual would have shown him that flight above the "engine critical altitude" was (engine) temperature-limited. Therefore, it was possible that the pilot had concentrated on the torque and not noticed an impending or actual engine over-temperature until after take-off. If he had reduced power to bring the temperature within limits, the torque and climb performance would have been reduced accordingly.

2.29 The pilot recognised a decreased climb rate, but by then the terrain was unsuitable for an immediate return to a hover or a landing, so he had to make an immediate turn away from the ridge and descend towards the lake in order to accelerate towards the optimum climb speed. He had not planned an escape route before take-off, and the further he flew across the lake, the less likely it was that the helicopter would be able to out-climb the surrounding ice cliffs.

2.30 The overlying winds at the summit altitude were strong. Therefore, it was probable that the helicopter entered descending air reflected off the lake walls and ice cliffs. Although the wind would have mixed with the air above the warm lake surface, the air temperature and humidity would both have been higher than at the take-off point, which would have raised the density altitude and decreased the rotor and engine performance and increased the power required.

2.31 The pilot took what was probably the only course of action now available: turning away from the ice cliff and instinctively flaring the helicopter to minimise its forward speed. The main rotor RPM increases as a result of a flare manoeuvre, so the sounding of the low RPM audio alarm shortly before impact suggested that the pilot had extracted as much lift as possible from the main rotor.

2.32 The pilot had no prior concern for the operation of the helicopter engine and considered that he had full power available throughout the take-off from the lake outlet. Although the engine-driven fuel pump was overdue for removal, there was no reason to suspect that it had been a contributing factor in the accident. Similarly, although dust could have entered the engine air control circuits while operating at low level on the weed task, the pilot had not reported a droop in engine speed, as had happened a year earlier (see paragraph 1.5.6). However, though considered unlikely, the possibility of some form of engine malfunction cannot be excluded.

Take-off weight

2.33 The destruction of the helicopter and the loss of some equipment meant the exact weight of the helicopter during the take-off from the outlet could not be determined. From the information available, the take-off weight probably exceeded the maximum certificated weight when carrying an internal load, possibly by up to 40 lb.

2.34 Although the pilot followed the operations manual requirement and lifted the packs to assess their weight, he was concerned only with not exceeding the maximum certificated weight, and did not consider, or appreciate, that performance considerations might have been more limiting. That oversight could have reflected his, and therefore the operator's, relative inexperience in operations at high density altitudes with a heavy helicopter.

2.35 The combined weight of the passengers not necessary for the task was 337 lb. If they had not been on board, the estimated weight of the helicopter would have been 2253 lb, comfortably below the out-of-ground-effect maximum weight for an assumed temperature of $+15^{o}C$ over the lake. More experienced pilots limit themselves to 3 persons on board unless conditions are particularly benign.

2.36 The pilot was mistaken in his belief that the aft cabin steps were included in the helicopter empty weight, as the steps were first fitted after the helicopter was last weighed, in May 2003, and they were also not included in the Summary of Empty Weight Changes. Because the steps were optional equipment, pilots of ZK-HDJ should have accounted for their weight on each flight when the steps were fitted, as the associated flight manual supplement required.

2.37 The items recorded on the form CAA2012 equipment list for ZK-HDJ varied from weighing to weighing, yet typically most of the whole range of items was always on the helicopter. Some items had a relatively light weight, but it is important that pilots know a helicopter's empty weight accurately, and what equipment is included in the empty weight.

Survivability

2.38 Passenger statements indicated that the main rotor blades hit the water during the turn and flare, causing the helicopter to tumble and the unrestrained front seat passengers to be ejected. The relatively low speed at impact and the proximity to the shore were factors in the accident being survivable.

2.39 All on board were fortunate that they were not more seriously injured. Ejection from a helicopter carries a high risk of being struck by a rotor blade. The DOC staff was misled in thinking that their survival was due to not wearing seat belts, because some of the passenger injuries would almost certainly have been avoided if everyone had been properly restrained.

2.40 Research data has discredited the belief of some people that being "thrown clear" of a vehicle aids survival. Seat belts greatly improve an occupant's chance of survival because there is less likelihood of receiving an injury that could hinder escape. Road safety programmes have not entirely countered the argument against the compulsory wearing of seat belts, and this accident suggested that participants in the aviation industry, too, might need further education.

2.41 On the weed task, the practice of flying unsecured could have developed to expedite boarding and disembarkation during the short transfer flights. However, the use of waist harnesses was already a concession to rapid movement on and off the helicopter, and it was not clear that their use met the intent of Civil Aviation Rule 91.207. Unless all of the weed flights had been conducted at low level and slow speed, those wearing only waist harnesses faced a high risk of injury in the event of an accident. The complacency regarding personal safety and the seat belt Rule was reinforced by the crewman's disregard of the Rule, and by the pilot's inability to see all of the passengers and thereby insist on compliance.

2.42 One passenger on the accident flight released his seat belt in an attempt to comply with the pilot's instruction for someone to jump out, but the others who were not wearing any restraint reflected the indifference to the use of seat belts that was seen during the weed task. As a result of this accident, DOC determined that there was a need to reinforce its seat belt instruction to staff.

2.43 The practice of removing the rear seats, to facilitate the carriage of mixed loads of passengers and cargo, increases the risk of injury to passengers in the event of an accident, because the seat structures were designed to absorb impact forces.

2.44 The Commission was concerned that the reasons for approved seats and seat belts were not understood and that, in some cases, a culture of disregard for the relevant Civil Aviation Rule existed. A safety recommendation was made to the Director of Civil Aviation that he address this safety issue.

2.45 The wearing of life jackets was not a direct consideration in this accident, although after the helicopter had descended low over the lake, the shore was likely to have been outside of the helicopter's autorotation range. The Commission was concerned that flights could take place in circumstances where the carriage or wearing of life jackets was not required by the Civil Aviation Rules, but a ditching was the only viable forced landing option. A common scenario is a flight close to a shore that has no beach suitable for a forced landing.

2.46 The Commission was of the view that if at any point in a flight a ditching is likely to have a better outcome than a forced landing onto unfavourable terrain, then life jackets should be carried. A safety recommendation was made to the Director of Civil Aviation that he address this safety issue.

2.47 The occupants acted promptly to provide first aid to the injured and use resources from the wreckage for shelter. Spare and shared clothing from the survey team compensated for the inadequate clothing worn by ranger B and the crewman. As a result of this accident, DOC reinforced its previously stated requirement for appropriate clothing and equipment in alpine situations.

2.48 Occupants of aircraft that are flown over hostile environments should be advised by the pilots and operators involved to wear clothing appropriate for the possibility of having to deal with a survival situation. The CAA has periodically included this advice in its *Vector* magazine[26] that is issued to licensed pilots, and the topic is implicit in the survival section of the theory syllabi for both private and commercial pilot licences.

2.49 The pilot's decision to tramp out for help was well considered and necessary, because radio contact from the accident site was uncertain and they risked hypothermia if there was a prolonged delay before rescue. The improvement in the weather and the proximity of one of the rescue helicopters assisted the rapid response, and the practised relationship between the rescue pilots and the mountain rescue team contributed to an efficient rescue.

[26] Most recently in the July/August 2007 issue.

3 Findings

Findings are listed in order of development and not in order of priority.

3.1 No technical defect was identified with the helicopter, but because of post-accident damage and deterioration to the engine, the possibility of reduced engine performance for an undetermined reason could not be excluded.

3.2 The take-off weight was estimated to have been 40 lb over the maximum allowable. It was highly likely that the take-off weight exceeded the maximum certificated weight.

3.3 The pilot's options for dealing with the load problem were reduced by having 2 unnecessary passengers who were inadequately clothed, but he could have returned them to the park headquarters before uplifting the survey party.

3.4 The helicopter did not have sufficient power, under the prevailing environmental and load conditions, to achieve a safe take-off.

3.5 The pilot did not have the mountain flying experience and knowledge of helicopter performance necessary for him to undertake safely the intended flight from Crater Lake.

3.6 The passengers' injuries would have been less severe if had they been properly restrained. The tacit approval of the crewman and various DOC staff for not wearing seat belts indicated that such non-compliance could be more widespread.

3.7 Pilots who carry passengers when the approved seating is not available or not used, or who do not ensure that passengers fasten their seat belts, expose those passengers to increased risk of injury in the event of an accident.

3.8 It was likely that the CAA's audit programme did not observe typical operator behaviour, because operators were usually able to show compliance with their expositions during an audit that was expected.

3.9 The inadequate clothing of the 2 unnecessary passengers decreased their survival chances, and possibly those of the whole group.

3.10 Operations over Crater Lake, or any other body of water, at low level risked breaching the Rule regarding the carriage of life jackets in a single-engine aircraft.

4 Safety Recommendations

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

4.1 On 18 December 2008, the following safety recommendations were made to the Director of Civil Aviation:

4.1.1 The Commission has determined that some helicopter operations are offered in mountainous terrain by pilots who have insufficient knowledge, experience or currency for those operations. Ensuring that their pilots have adequate role training and supervision can be problematic for smaller scale operators. The Commission recommends that the Director of Civil Aviation addresses this safety issue. (034/08)

4.1.2 The Commission has determined that there is evidence that the purpose of approved seats and berths and the value of seat belts in helicopters are not understood or are disregarded, and that in some operations there could be a culture of non-compliance with Civil Aviation Rules relating to passenger restraint. The Commission recommends that the Director of Civil Aviation addresses this safety issue (035/08)

4.1.3 The Commission has determined that the current format of the CAA's audit and surveillance programme might not be effective for determining the true level of industry compliance with Civil Aviation Rules. The Commission recommends that the Director of Civil Aviation addresses this safety issue. (036/08)

4.1.4 The Commission has determined that there is no requirement for the carriage or wearing of life jackets on a flight during which, in the event of a forced landing, a water landing was likely or preferable. The Commission recommends that the Director of Civil Aviation addresses this safety issue. (037/08)

4.2 On 12 December 2008, in response to the preliminary issue of the above safety recommendations, the General Manager Safety Information for the CAA replied, in part:

> in principle there are no issues with the report's findings or suggested preventive actions.

5 Safety Action

5.1 The pilot attended a CAA training workshop for Senior Persons responsible for Air Operations in August 2008. The aim of the workshop was to equip senior persons, chief pilots, flight operations managers, and chief flying instructors with an awareness of the responsibilities of their positions, and to cover the knowledge and tools needed to be an effective senior person.

Approved on 18 December 2008 for publication

Hon W P Jeffries
Chief Commissioner

Appendix A
Helicopter pilot licences: outline of mountain flying training requirements

Refer to the relevant Advisory Circular for current requirements.

Private pilot licence (helicopter), reference Advisory Circular 61-3

Total flight experience
At least 50 hours' total flight experience in helicopters, except for allowable cross-crediting. These times are to include at least the minimum flight time requirements that follow:

Mountainous terrain flight training
5 hours in helicopters, which is to include 3 hours' dual instruction and 1 hour's solo flight time.

Piloting technique test – mountainous terrain awareness
On a knoll or spot on a ridge perform a reconnaissance, determine the wind direction and report it, then carry out a circuit with power check and safe approach to a hover or landing as applicable. In no-natural-horizon conditions, demonstrate flying in a valley terminating in an approach to a hover or landing as applicable at a position nominated by the flight examiner. This item may be omitted from the test if a Category B or A flight instructor has certified the candidate's competence in the candidate's log book.

Commercial pilot licence (helicopter), reference Advisory Circular 61-5

Total flight experience
At least 150 hours in helicopters, or 125 hours in helicopters if a full course of approved training has been completed…
These times are to include at least the minimum flight time requirements that follow.

Mountainous terrain flight training
10 hours in helicopters, which is to include 7 hours' dual instruction.

Piloting technique test - mountainous-terrain awareness
On a knoll (or spot on a ridge) perform a reconnaissance, determine the wind direction and report it, then carry out a circuit with power check and safe approach to a hover or landing as applicable. In no-natural-horizon conditions, demonstrate flying in a valley terminating in an approach to a hover, or landing as applicable, at a position nominated by the examiner. This item may be omitted from the test if a Category B or A flight instructor has certified the candidate's competence in the candidate's logbook.

Airline transport pilot licence (helicopter), reference Advisory Circular 61-7
There are no additional mountain flying requirements.

Appendix B
Helicopter performance

References: 1. "Helicopter Performance", *Good Aviation Practice* series, CAA, Wellington, 2002.
2. *Rotorcraft Flying Handbook*, United States Department of Transportation, FAA-H-8083-21, Washington DC, 2000.

Pressure altitude

An International Standard Atmosphere (ISA) has been established to enable comparison of aircraft performance, calibration of altimeters, and other practical uses. The ISA assumes a particular pressure and temperature distribution with height and also assumes dry air. In the ISA, any pressure level has a standard corresponding altitude called the *pressure altitude* and a corresponding temperature called the *ISA temperature*. Pressure altitude is the height that will register on a sensitive altimeter whenever its sub-scale is set to 1013.2 hectoPascals, so a pilot can readily find the pressure altitude to use to calculate expected take-off performance.

Density altitude

Warm air is less dense than cold air. Thus, when the temperature at any altitude in the atmosphere is greater than the temperature would be in the standard atmosphere at the same altitude, the air at that altitude will be less dense than in the standard atmosphere.

Density altitude represents the combined effect of pressure altitude and temperature. It is the altitude in the standard atmosphere where the air density is the same as that at the particular location being considered.

As altitude increases, the decreasing temperature and pressure have opposite effects on the air density, but decreasing air pressure has the dominant effect and the density decreases. As air density decreases, performance decreases. Conditions that result in high density altitudes are high elevation, high air temperature, high humidity and low atmospheric pressure.

Engine and (both main and tail) rotor performance are highly dependent on air density, although at lower altitudes the power output of a turbine engine is usually less affected than that of a reciprocating engine. In practical terms, an increase in density altitude has a number of effects on helicopter performance:

- reduced hover ceiling, which often means the choice of take-off and landing sites available to the pilot becomes more limited
- reduced operating power margins, which means reduced payloads
- reduced rate-of-climb performance, which means obstacle clearance can be adversely affected.

At higher gross weights, the increased engine power required to hover produces more torque that must be countered by increased tail rotor thrust. Tail rotor performance is affected by increased density altitude in the same way as the main rotor. On some helicopter types, at high density altitude, the tail rotor might not be able to produce the required thrust, even though the gross weight is within limits.

Ground effect

When a helicopter hovers within a few feet of a smooth, level surface, the main rotor downwash is reduced because the airflow is turned as it contacts the ground. This has the effect of increasing the lift of the main rotor blades and therefore the power can be reduced slightly to prevent the helicopter from climbing. The reduced power requirement to hover is called *ground effect*. The power check conducted before take-off is usually performed with the helicopter *in-ground-effect*.

The opposite effect occurs when the helicopter hovers *out-of-ground-effect*. In order to prevent the helicopter from descending, additional power is required. Therefore, the out-of-ground-effect hover ceiling is lower than the in-ground-effect hover ceiling.

Reference 1 advises that performance calculations should be conservative and based on an out-of-ground-effect hover unless the following criteria are met:

- adequate pilot familiarity with, and current experience on, the helicopter type
- an accurate assessment of the helicopter weight
- pilot familiarity with the landing zone
- accurate knowledge of the ambient conditions at the landing zone.

Take-off performance and techniques

For any given weight, the higher the density altitude at the take-off point, the more power required to hover. Under some conditions, there might be insufficient power to take off and clear obstacles on the climb-out path. This is why the power margin must be assessed before every take-off.

When there is horizontal airflow across the rotor, either from the wind or from movement of the helicopter, *translational lift* occurs. The phenomenon is most noticeable at about 15 to 25 knots airspeed, and the increased lift and consequent reduction in power required can be a timely bonus if performance is marginal. By taking off into wind, translational lift is achieved earlier, resulting in a steeper climb angle.

Take-off (and landing) into wind is strongly preferred because of the lower ground speed, reduced power requirement and easier obstacle clearance. However, in mountainous terrain, such as a basin, the wind speed and direction can be difficult to assess and both may vary considerably over a short period. Light winds can be particularly difficult, if they swing from being a head wind to a tail wind and the benefit of translational lift is lost.

A *cushion creep* take-off is a technique used when the power margin is small and the pilot wants to maintain the benefit of ground effect while accelerating through translational lift. However, if the transition to forward flight is conducted over ground that slopes away, such as a sharp ridge feature, the main rotor might effectively be out-of-ground-effect and the power required may be greater, not less.

A pilot should always determine a *decision point* at which a take-off can be abandoned or a landing approach discontinued if it is not going according to plan. For a take-off, the decision point should allow sufficient distance and height to bring the helicopter to a hover safely or to accelerate to a safe speed down a pre-determined escape route.

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01-005R	Bell UH-1H Iroquois ZK-HJH, in-flight break-up, Taumarunui, 4 June 2001

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