TANGIWAI RAILWAY DISASTER

Derailment of Wellington – Auckland Express at Whangaehu River Bridge between Tangiwai and Karioi railway stations on 24 December 1953

REPORT BOARD OF INQUIRY

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Transport Accident Investigation Commission
as a reminder of a New Zealand rail accident that
claimed the lives of 123 people.

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Tangiwai Railway Disaster

Report of Board of Inquiry

R. E. OWEN, GOVERNMENT PRINTER, WELLINGTON

THE HON. MINISTER OF RAILWAYS.

Sir,

Derailment of Wellington-Auckland Express at Whangaehu River Bridge Between Tangiwai and Karioi Railway Stations on 24 December 1953.

By your warrant dated 18th day of January 1954 we were appointed a Board of Inquiry and required and authorized to inquire into and report to you concerning the derailment of a Wellington-Auckland express train while running between Tangiwai and Karioi Railway Stations on the 24th day of December 1953. In consequence of such derailment a number of passengers who were travelling in the said train lost their lives, and other passengers were injured and damage was done to the rolling stock comprising the said train.

The matters on which we are required to inquire into and report to you are as follows:

(1) What was the cause of the accident?

(2) Whether at any material time or times any person in the service of the New Zealand Government failed to exercise reasonable care or to fulfil any duty or responsibility reasonably to be expected of him in relation to the circumstances leading to the accident.

(3) Generally, to inquire into and report upon such other matters arising out of the accident as may come to our notice in the course of our inquiries and which we consider should be brought to your attention.

(4) What steps (if any) should be taken to prevent a similar accident?

We were originally directed to report to you by the 27th day of February 1954, but that date was extended to the 14th day of April, and later to the 30th day of April 1954.

We have held an inquiry as directed and now have the honour to report as follows:

THE INQUIRY

Public sittings commenced at Wellington on Tuesday, the 26th day of January 1954, and terminated on Friday, the 2nd day of April 1954. The following counsel represented various interested parties:-

Messrs N. R. Bain and R. A. Burns for the Railways Department and other Government Departments.

Messrs E. D. Blundell and H. R. C. Wild for the E.F.C.A. and the A.S.R.S.

Mr S. G. Stephenson for the Professional Engineers' Association of New Zealand, Incorporated.

Messrs J. H. Oakley and T. P. McCarthy for the relatives of certain victims.

Mr Ian Macarthur for relatives and friends of victims not otherwise represented.

Mr R. Hardie Boys to assist the Board.

Mr A. R. Tarr, General Secretary, N.Z. Railway Officers' Institute Incorporated represented that organisation.

Various witnesses as detailed in the Schedule attached hereto and marked "A" were called and examined or their statements were admitted by consent.

In addition, voluminous correspondence from organisations and citizens was received and considered.

Exhibits produced or admitted by consent are as detailed in Schedule "B".

Depositions of the various witnesses, together with a record of formal submissions by counsel and other representatives, are recorded in the bound volumes Nos. I to V accompanying this report.

NARRATIVE

On 24 December 1953 the 3 p.m. Wellington to Auckland Express, referred to hereafter as No. 626, left Waiouru Station at 10.9 p.m.

It consisted of:

			Number of Seats	Lettered	Tare Weight			Total Weight		
					T.	cwt	qr	T.	t	qr
Postal van … …	FP	707			22	12	2	25	2	2
Van … …	F	592			22	14	3	31	14	3
First-class car …	A	1889	31	W	30	13	1			
	A	1857	31	V	30	6	2	96	18	3
	A	1887	31	X	30	2	0			
	AA	1717	29	Z	27	13	2	29	7	1
Second-class car …	A	1920	56	A	27	17	1			
	A	1862	56	B	27	13	0			
	A	1915	56	C	27	9	0	152	5	1
	A	1899	56	D	28	1	0			
	A	1907	56	E	27	14	1			
Locomotive ...	KA	949	…	…			…	131	8	0

Total weight of train, 467.3 tons.

Total length of train over buffers, 704 ft. approx.

It was manned by Messrs Charles John Henry Parker as Engine Driver, Lancelot Redman as Fireman, William Ian Inglis as Guard, Hemi Matiaha Ransfield as Assistant Guard, and William E. Allaway as Car Attendant. There were aboard, in addition, two postal officials travelling in the postal van at the rear of the train. Evidence obtained from police inquiries up to the date of this report established that the total number of persons on the train was 285. Of these, 134 are known to be safe and 131 bodies have been recovered. Of the 131 bodies recovered, 123 have been identified, the remaining 8 having been buried unidentified. In addition, a further 20 persons are not accounted for. Thus the records show a total casualty list of 151 persons. Many of the passengers were travelling on holiday to or from their homes, and no doubt many planned to be in Auckland during the visit of Her Majesty the Queen who landed there on the previous day. The night was clear and the weather fine.

The maximum speed authorised for an express train between Hihitahi, south of Tangiwai, and Ohakune, to the north, is 50 miles per hour. Tangiwai is a flag station attended by Station Agents and is situated 235 miles 18 chains from Auckland and approximately one mile from the crossing to the north of the Whangaehu River by Bridge No. 136.

No. 626 passed through Tangiwai Station on time at 10.20 p.m. at a speed described by the Station Agent in charge as "approximately 40 miles per hour" and as "going slower than usual". The engine headlight was on, some carriages were still lighted, as also were the tail and side lights on the last vehicle of the train. A witness on the road on the north bank of the river observed the north-bound express approaching from the south. He saw the headlight of this express as it crossed the level crossing just north of the Tangiwai Railway Station. To his mind it was travelling fast for the express. As it approached the bridge the train definitely slowed down, and it appeared to him the driver had shut off the steam. His impression is that as the locomotive entered on to where the bridge usually was it appeared to him that it had reached about the northernmost span when it suddenly nose-dived into the river. The tender and some carriages were seen to plunge in with the locomotive. He states the rest of the train was left stationary with the lights burning in the carriages. The noise of the roaring river and boulders, but mostly thick water, was in his words "terrific", and he could not hear the train crash as it plunged into the river. The waves of the river surges, he states, were 8 ft. to 10 ft. high.

Mr A. C. Ellis observed the approach of the train on the southern bank, and reaching the track waved a torch to stop the train. It seems clear that either that action or the observation by the locomotive crew in the headlight beam of the condition of the bridge and river caused the driver to make an emergency application of the brakes. They were applied some distance before reaching the bridge, but in insufficient time to prevent the disaster. Subsequent examination revealed that the fuel-oil supply tap was turned off, and its peculiar construction makes its clear this was done by the fireman. It was later shown that the locomotive, tender, and all five second-class carriages had plunged into the torrent. Cars X and Z, first-class carriages, were left standing on the remaining portion of the bridge with the rest of the train on the track to the south. Car Z, after a short period of time, also fell into the torrent.

The Board proposes now to examine the facts from which it may find an answer to each section in the order of reference.

ORIGIN OF FLOOD

The Board has had the assistance of a report of James Healy, Superintending Geologist, Geological Survey Branch of the Department of Scientific and Industrial Research. He holds the degree of Master of Science. He examined the Tangiwai area on 26 December 1953, and on the morning of 28 December 1953 he flew over Mount Ruapehu. That afternoon he inspected on foot the Whangaehu River where it crosses the boulder fan between the mountain and the Desert Road. He climbed Mount Ruapehu on 29 December 1953, 8 January 1954, and 13 February, and examined the Crater Lake and the head of the Whangaehu Glacier. Additional visits to Tangiwai were made on 7 January 1954, 12 February 1954, 15 February 1954 and 23 to 26 March 1954. From observations made during these visits and from other information that has been collected Mr Healy prepared an account of the cause and nature of the flood at Tangiwai on 24 December 1953, which the Board adopts. It is a matter of interest to record that having perused the report since its submission to this Board Dr C. A. Cotton, for some time Professor of Geology of Victoria University College and now retired, has informed this Board by letter (*inter alia)* that he finds himself in close agreement with the opinions expressed by Mr Healy as to the cause of the flood of 24 December 1953.

Mr Healy's report is as follows:

Ruapehu Crater Lake: The summit of Ruapehu consists of an outer rim, enclosing an area about a mile ling from north to south and half a mile wide, within which there is an inner volcanic cone with a central crater occupied by a lake. Permanent fields of snow and ice fill the depression between the inner cone and the outer rim on the south, west, and north, but on the east the outer slopes of the cone, which reaches its highest altitude at the Pyramid or Cinder Peak, fall steeply and directly to the Whangaehu Glacier. I produce sketch plan (Exhibit 21) and model (Exhibit 22).

The main part of the Whangaehu Glacier lies east of the Pyramid, but the south-west branch heads back between the Pyramid and Mitre Peak, south-east of the crater lake.

The lake has been reported to have frozen over on two occasions only in the past, but generally it is warmed by volcanic steam fed in from below, is warm in patches, and has at times steamed strongly. Consequently it tends to melt the ice that comes into contact with it, and, in my opinion, the ice does not form an effective barrier to the water. Although some of the water no doubt seeps away through the walls of the ash and scoria cone, at which point the water spills over, melts a channel beneath ice, and finally emerges to form a branch of the Whangaehu River at the foot of the south-west branch of the Whangaehu Glacier. The lowest point in the volcanic rim is at the south end of the lake, and the presence there of an ice cave leading to the Whagaehu River has been known for some time.

In March of 1945 an island of steaming lava emerged above the surface of the lake, and after a temporary disappearance grew to form a large dome that mushroomed out over the crater floor. The water of the lake poured out through the ice cave, which was enlarged by the hot water, until finally the lake was almost empty of water and the lava reached the entrance to the cave. After this came the explosive phase of the eruption, which lasted until early in 1946, leaving a crater about 1,000 ft. deep and the summit of the mountain covered deeply with ash and other volcanic debris.

The crater immediately commenced to fill with water again, rapidly for the first year or two, and then more slowly. By September of 1952 the level of the lake was about 35 ft. below the level it finally reached some time about August of 1953. By the latter date the level had stabilized, and some outlet cave had again formed. The lake remained at the same level for at least four months prior to 24 December 1953. Mr and Mrs T. Wood, of Auckland, visited the lake on that morning, and reported that there was a cave at the south end of the lake. The ice had sufficiently thawed by then for a photograph (No. 38 in Exhibit No. 23) taken by them to show the cave occupying the lowest notch in the volcanic rim, with outcrops of volcanic rock showing on each side. The lake at this time was about 20 ft. to 25 ft. higher than it was before 1945, due to the fact that the erupted volcanic material had raised the rim of the cone. The condition of the lake as shown in the photograph does not indicate to me the imminence of any break in the crater wall.

When I inspected the lake after the Tangiwai flood I found that where there had been outcrops of volcanic rock to the right or west of the cave there was another huge cave apparently formed by the collapse of that rock. The roof of the earlier small cave could be seen above a pile of fallen ice at the front of the large cave, and by 29 December 1953 the lake level had fallen by about 27 ft. The large cave was about 150 ft. wide and about 100 ft. high at the entrance, but the size diminished rapidly inside, and the floor fell away steeply from the lake. A stream was flowing from the lake beneath a pile of fallen ice into the cave. By 13 February 1954 the lake level had fallen another foot and the pile of fallen ice had grown until it nearly blocked the entrance to the cave.

Along the south-west and west side of the lake was exposed a rock bench of andesite lava, with vertical walls extending down to lake level. This is the remaining fringe of the lava that flowed out on the to the crater floor in 1945, and it lies beneath volcanic ash and scoria which are covered with ice. The southern end of the lava forms a spur that projects half-way across a poorly consolidated blue-grey mud that probably formed the floor of the lake before 1945, and on which the lava presumably lies.

The explanation offered for the collapse is that while the lake was discharging through the first formed cave, water must have also been seeping through the volcanic ash and scoria alongside, to form another channel beneath the ice at lower level. Erosion in this channel may have reduced the strength of the ash barrier, and cracking movements in the ice above may have caused it to suddenly collapse. A number of crevasses had developed in the icefield above the cave within a week of the flood, and by 13 February 1954 the number and size of the crevasses had increased.

I found no evidence that volcanic activity had played any part in causing the sudden collapse of the ash barrier, but this cannot be definitely ruled out. Mr G. Eiby, of the Seismological Observatory, reported that the seismograph at the Chateau did not record any earthquake or volcanic disturbance, but it recorded vibration, presumably caused by the rush of water, commencing two or three minutes after 8 p.m. on 24 December 1953. It is suggested, therefore, that as a result of crevassing movements in the ice the ash barrier alongside of the existing cave suddenly collapsed about 8 p.m. on that date and precipitated a solid mass of water down the channel to the Whangaehu River beneath the ice.

The Whangaehu Glacier: The aerial inspection of 26 December 1953 showed that for a quarter of a mile along the lower end of the south-west branch of the Whangaehu Glacier the ice was broken, and the stream was flowing in the open in a rocky gorge flanked at high level by jagged and cracked vertical walls of ice. At the head of the glacier, between the Pyramid and Mitre Peak, there was, in addition, a large collapse hole in the ice, on the north wall of which was a waterfall where the stream from the lake emerged from a cave beneath the ice, fell vertically for over 100 ft. or more, and disappeared again beneath the ice. Between the collapse hole and the head of the open gorge remained an ice bridge about 100 yards across.

In March of 1945, when hot water was pouring from the crater lake, the same two places were also free of ice on account of melting. The ice is presumably thin, and when the mass of water from the crater lake surged down the channel on the night of 24 December 1953 either the vibration and pressure cracked and shattered the ice, or a temporary blockage beneath the ice caused pressure to mount until the ice gave way. Huge masses of broken ice must have been carried away by the flood.

The Whagaehu Gorge: Down the slopes of Ruapehu the Whangaehu River flows for five miles in a rocky gorge. I examined the gorge from the air on 28 December 1953, and found that along its length the lower slopes were darker in colour than elsewhere, as though they had recently been cleared of loose debris by a flood. On the same day I reached the lower end of the gorge on foot and saw evidence of recent flooding. The flood as it moved down must have cleaned out large quantities of loose ash and boulders collected in the valley over a period of years.

At the lower end of the gorge the flood at its maximum filled a channel 105 ft. wide to a depth of 22 ft. At the time of my visit the Whangaehu River occupied a channel 20 ft. wide and 1 ft. 6 in. deep. A mile above the lower end of the gorge the flood was running high enough to overtop a low saddle, and part went down a dry gully south of the main one.

The Boulder Fan: At the foot of Ruapehu the Whangaehu River emerges on to a large boulder fan that extends eastward for three miles towards the Desert Road. The river normally occupies a single channel across this, but it is intersected by numerous branching dry, shallow gullies. On 28 December 1953 these showed signs of recent flooding, indicated by a small amount of scouring on vertical banks at the outer sides of bends and by the deposition of fine silt. The flood of 24 December 1953 swept from Ruapehu on to the boulder fan and spread across all the watercourses, after which the various streams reunited at the base and moved on towards Tangiwai.

The small amount of erosion that occurred across the boulder fan indicates that the flood was fully loaded by the time it reached the fan. It must have been carrying large quantities of volcanic ash and boulders and could be classed as a lahar.

The Term "Lahar": A lahar is a type of mudflow that occurs in volcanic areas. Lahars may be formed by the waters of crater lakes being released by the collapse of the crater wall or by volcanic eruption, by the melting of snow and ice by volcanic heat, or by the action of rain on volcanic ash deposited on the steep slopes of volcanoes. They usually pick up large quantities of volcanic ash and other debris, and form a thick slurry that on account of its high density may carry even enormous boulders for many miles across fairly flat country once the initial momentum has been gained.

The flood from Ruapehu on the night of 24 December 1953 was of this type, and is classed as a lahar.

The Lahar at Tangiwai: The lahar reached Tangiwai about 10.10-10.15 p.m. in the form of a dense wave of water, sand, and boulders. While the lahar passed there seems to have been little or no erosion, and the shingle flat in which the river flows was smothered with a swiftly moving mass of sediment. Above the railway bridge the flood spread out across the flats, depositing sand and boulders, and reached a depth of 20 ft. at the bridge. It piled up to cross the highway and highway bridge, depositing sand and flooding across the highway for several hundred yards, and swept on down the river. Along the banks the vegetation was quickly buried by sand, but on the bed of the channel vegetation was flattened and abraded.

From calculations and tests within his Department it is stated the density of the lahar at Tangiwai Bridge was roughly 1.6, which means the lahar would have a transporting ability many times that of a normal river in flood. He suggests this supports the theory that Pier 4 was carried away bodily in the first stage of the lahar.

In the opinion of the Board the term "lahar" is a term more frequently used by geologists than civil engineers. It is, however, a convenient generic term for use by civil engineers; in fact, it might well be advantageous if in the future the general public had more understanding of the destructive nature of a lahar.

WHANGAEHU RIVER

From drawings supplied by Roger Wilson Harris, Chief Engineer of the Rangitikei Catchment Board, and handed in as exhibits it is shown that above Tangiwai the Whangaehu River has three main tributaries, the Wahianoa, Makahikatoa, and Whangaehu itself.

The Whangaehu proper flows down the mountain side from the Crater Lake for approximately eight and one-half miles in an easterly direction, then turns abruptly to the south at the bottom of a fan, runs more or less parallel with the Desert Road for approximately six miles, thence in a south-westerly direction towards Tangiwai. The total distance to Tangiwai is approximately twenty-five miles.

The lower nine miles runs through or bounds part of the Karioi State Forest. Above this is an area of tussock, snow grass, etc., with diminishing vegetation as the height increases. An extensive fan of volcanic materials exists between mileages 16m. to 19m., with a number of channels showing. Both above and below this area the river is fairly well confined with the exception of a division into two channels in the vicinity of mileage 9m.

The actual catchment area above Tangiwai is approximately 50 square miles, including the mountain area.

PROGRESS OF THE FLOOD

The following extract from the evidence of Charles William Oakey Turner, Engineer-in-Chief, Ministry of Works, gives a general picture of the flood which the Board adopts:

Judging by published statements by a number of observers it appears that even at the beginning of this year the area of Crater Lake, the extent of the drop in surface level, and the structure of the discharge weir were not confidently known. A Senior Engineer of the Works Department, who is also an experienced alpinist, was therefore sent to the lake with instructions to make measurements and observations. Using control measurements obtained by this engineer the Aerial Mapping Branch of Lands and Survey through aerial photographs computed the area as 72 acres before the break-out and 47 acres afterwards. From the evidence available at the site the drop in the level of the lake during the flood was measured as 26 ft. The engineer computed the corresponding total volume of water discharged, measured the width of the discharge lip or weir as approximately 100 ft., and thence computed roughly the rate of outflow. While these calculations are only approximate they give the order of magnitude of discharge and time to lower the lake. His report indicated that the lake fell by approximately 20 ft. in 150 minutes. During the discharge of the first 20 ft. it is believed the flow varied from an initial maximum of about 30,000 cu. ft. per second to about 1,300 cu. ft. per second. The remaining 6 ft. then discharged comparatively slowly.

The very high discharge rate adequately explains the erosion of the mountainside and the great volume of silt and boulder-laden water concentrated at the bridge site. It is impressive to consider that 30,00 cu. ft. per second is the estimated ultimate flood volume for the Waikato River at Maraetai.

The flood following the release of water from Crater Lake would be of the most violent type. It would proceed down the mountain as a wave uplifting huge quantities of sand, silt, and boulders. This load would be temporarily dropped wherever the speed of flow was checked due to spread of the river bed and again picked up as the water accelerated and regained speed by flowing off and over the raised bed so formed. While it is believed that the discharge would be spread along the river it appears likely from this evidence and from an inspection at the site that the volume of flood at the bridge was 30,000 cu. ft. per second or greater.

About one-third of a mile above the bridge the river channel widens for a comparatively long straight run. The extensive widening, the right-angle bend above the bridge, and the restriction of the bridge opening would all tend to cause a large drop in velocity, which in turn would give rise to a corresponding and almost instantaneous deposition of bed material that would raise the river bed. The evidence on the site above the bridge is, in my opinion, consistent with this conception. From the temporary built-up river-bed water would flow away at high velocity for a short time. The steep front of the accumulated material would, however, quickly be eroded and would start to flow through the bridge openings. While I have separated these happenings it must be emphasized that the sequence of events would be very rapid and the individual effects are difficult to separate. The final surge of the piled up flood wave would free enormous loads of material and the immediate result could well resemble the mud flow or lahar which has been described. The effective weight or density of the fluid would be substantially greater than that of water, and that in combination with its considerable lateral load on the river bed and on the bridge piers.

There was no sign of abnormal rainfall in the catchment preceding the accident, nor was there any evidence that the two tributaries (Wahianoa and Makahikatoa) contributed anything other than their normal low flow.

Inspections of the river at various points, together with a study of the aerial photographs, confirm the view that a large discharge from the lake advanced to the railway bridge slowed down only by bed resistance. This resistance was increased by the high density of the lahar. Continued discharge from the lake tending to overtop the advancing front increased its height and caused temporary ponding on the straight stretch of river upstream of the bridge.

Assuming an average speed of advance of the crest to be 10 miles per hour, approximately two and a half hours would elapse from the time of release of the waters to their arrival at Tangiwai at 10.17 p.m. It is clear that a resident of Waiouru heard an unusual roaring sound from 8 p.m. onwards on the evening of 24 December. The accident occurred at 10.22 p.m., and it is a fair assumption, we think, that the crest arrived at least some minutes before this time. It is established that the flow past the railway bridge had diminished considerably by 10.35 p.m.

A flood rise of 15 ft. to 17 ft. has been measured at the railway bridge (i.e., above the bed as after flood) and slope area measurements give a mean discharge of approximately 23,000 cusecs. This agrees with the general opinion that the peak discharge was approximately 30,000 cusecs.

Besides the destruction of the road and railway bridges at Tangiwai three further bridges were also destroyed all within the Waimarino County. These are (i) a private bridge (Strachan's) in the vicinity of the Karioi State Forest Depot (a low level structure), (ii) the Ngamoki Bridge, (iii) Whangaehu Valley Road Bridge. Although a number of tributaries in the Tangiwai vicinity were backed up to abnormal heights no further serious flooding or further reports of flood damage were recorded.

It is not known for certain how far downstream the flood wave moved in its original form, but it would tend to flatten in the Whangaehu Valley proper owing to an increasing cross-section and a very tortuous course. It is, however, significant to note that the steel underframe of Car "A" 1920-"A" on the train-was carried approximately one and a half miles downstream from the railway bridge.

The flood is estimated to have arrived in the lower reaches at the State Highway Bridge, Whangaehu, at approximately 3.30 p.m. on 25 December 1953, a distance of approximately 70-80 river miles from Tangiwai. The flood rise was between 3 ft. and 4 ft. above normal river level. Observers reported that the river was then very dirty and carried large quantities of debris and logs, the timber being mostly willow. For comparative purposes it is recorded that a serious flood in the lower reaches in the Whangaehu River causes rises in the water level of up to 20 ft. or more.

INCIDENTS OF THE FLOOD FROM SUBSEQUENT INSPECTION

Upstream from the Railway Bridge

Wherever the river abruptly changed its course large boulders were deposited. There were many up to 4 ft. in diameter, and a number of considerably larger size. Large quantities of material, generally described as sand, were deposited, and it is evident the river had been heavily laden with a mixture of boulders and sand.

At these abrupt changes of course where a river strikes a bank or bluff some erosion occurred, but the comparatively small erosion considering the height and violence of the flood indicates that the peak was of short duration.

Downstream from the Railway Bridge

It is evident that large boulders passed through the gap of the railway bridge, for two of the 5-ton concrete blocks from the vicinity of Pier 4 are to be seen some 60 yards downstream from the road bridge with a boulder of at least the same weight resting on top of them.

There are numbers of boulders downstream from the railway and road bridges, but the mass does not extend far, and even at the gorge a little downstream from the remains of Car No. 1920 (A) the boulder deposit is small in comparison with that at and upstream from the railway bridge.

On the reach approaching this gorge, however, enormous quantities of sand were deposited, and this sand deposit was evident at the suspension bridge and at the bridge site on the Karioi-Wanganui Road.

Plan No. 69100/17, Exhibit No. 1, shows the maximum flood levels, datum being 100 ft. below rail level at the southern abutment of the bridge.

Individual flood levels near the bridge, and particularly towards the right bank of the river, are not conclusive as they may have been the result of turbulence caused by the bank itself or by other obstructions, but the general pattern is a guide to the situation which existed.

On the upstream side and near the south end of the bridge the maximum flood level was about 93 and on the downstream side 85. This difference of 8 ft. was probably not the maximum since the highest flood level on the downstream side would not occur later than that on the upstream side.

The levels on the downstream side fall rapidly to 85 at a point about 200 ft. below the bridge, which coincides with the highest observed flood levels on the downstream side near the railway embankment.

Approaching the railway bridge the flood gradient is fairly even until it reaches a point about 20 chains above the bridge. From this point it flattens considerably, indicating a velocity check, and probably caused initially by the sharp bend in the right bank and augmented by the bridge piers.

It is appropriate to mention at this stage that high water marks on piers Nos. 6 and 7 indicated that the flood level upstream was higher at pier No. 6 than at pier No. 7.

BRIDGE No. 136

Bridge No. 136 over the Whangaehu River is situated at railway mileage 234 miles 20 chains between Karioi and Tangiwai. The Main Trunk line was built by the Public Works Department and handed over to the Railways Department. The bridge was built about 1906, and it consisted from the northern end in sequence, of-

1/22 ft. 0 in. plate girder span.
2/44 ft. 0 in. plate girder spans.
4/22 ft. 0 in. plate girder spans.

The 44 ft. 0 in. plate girder spans were constructed to Public Works Department Plan No. 19395 (68100/2) and the 22 ft. 0 in. spans to Public Works Department Plan No. 17735 (68100/3), both included in Exhibit No.1. These plans were not drawn specifically for bridge No. 136, but were amongst the standard plans then used by the Public Works Department elsewhere in New Zealand.

The total length of the bridge was 198 ft. 0 in. The piers and abutments are of mass concrete and were constructed to the arrangement shown on Public Works Department Plan No. 25175 (68100/18-Exhibit No. 1). This plan is one in a folio of plans recorded in Wellington from the records of the Railways Department. It is the plan which shows the location and dimensions of the bridge piers and would be the plan issued to the construction works. The depth of the foundations shown is not in accord with the bridge as built, and this is accounted for by the final fixing of foundation depths at the site after the ground is opened up. The Board is of the opinion that all relevant information then available as to the river's origin, characteristics, and vagaries would be considered by the engineer in charge of construction. Inquiries for plans and records of the original bridge were started immediately after the accident. It was discovered that the Wellington files had been destroyed in the fire in the Hope Gibbons Building, Dixon Street, Wellington, in which they had been stored. These files would contain letters of instruction regarding the construction of the bridge, instructions relating to standards of workmanship, and reports from the construction works and descriptions of the foundations as opened up at the site. Search in Taranaki and Wanganui district and sub-offices was fruitless. There appears to be no Public Works Department plan in existence showing the bridge as actually constructed. No record has been found as to the depth to which the foundations were carried, and the details of some of the foundation depths shown on Plan No. 68100/1, Exhibit No. 1, have been obtained subsequent to the accident.

The issue of typical bridge plans leaving the foundation depths undefined is in accordance with standard practice for bridges of the type under review as is the practice of the engineer in charge of construction deciding the depth of foundations.

The first indication on the Railways Department's files of damage to the bridge is on 23 January 1925 (see District Engineer's file 2443/8, Exhibit No. 31). The Acting District Engineer (then stationed at Ohakune) reported to the Chief Engineer (*inter alia)* as follows:

> Yesterday afternoon a heavy swell came down the Whangaehu River, the river rising about 9 ft. and going down through the night to almost normal this morning.
>
> There was a fairly heavy scour on the upstream side of pier No. 4, this pier evidently having tilted over about half an inch.
>
> The track showed a bulge, towards the upstream side of about half an inch over this pier.
>
> . . . . . .
>
> The depth of the scour is about 9' 0" below the top of the footing but there are no marks on the pier to show the depth in the ground and I have been unable so far to ascertain the depth of pier in the ground. From the only plan of bridge I have the depth of footing is shown as about 2' 0" and if this is the case the scour extends about 6' 0" below the foundation. The plan apparently is incorrect as I have tried the face of the pier with a pole and judging by the feel of it the concrete footing extends for the full depth of the scour.
>
> . . . . . .
>
> I am unable to account for the heavy rise in the river as there has been no rain in the district for the past fortnight.

A note on file CE. 19592/11, Exhibit No. 39, shows that the Public Works records disclosed no information concerning the depths of foundations; this is dated 30 January 1925.

The District Engineer was advised accordingly and instructed that should the scour undermine the foundation it should be underpinned by placing cement in sacks beneath the concrete and the hole then filled up with rock.

The records do not disclose whether underpinning was carried out, but it was clear that the hole was filled with rock. From this it can be assumed that no underpinning was necessary.

The next record of damage was on 9 March 1936 (District Engineer's file 2443/27, Exhibit No. 31) when the Foreman of Works reported scour at Piers Nos. 3 and 4 and recommended 15 wagons of stone protection. This work was done and advised complete by Foreman of Works on 18 June 1936.

On 1 March 1944 the Foreman of Works reported to the District Engineer, having been called to the bridge to inspect Pier No. 3 on 28 February 1944.

He reported that the river was in high flood and that a whirlpool had scoured a hole 10 ft. in diameter and 3 ft. deep on the upstream side of this pier. No damage was done to the foundations and the hole was filled in with stone.

On 25 June 1946 (District Engineer's file 2443/38) the District Engineer instructed the Foreman of Works regarding the placing of eight 5-ton concrete protective blocks in the vicinity of Pier No. 4.

The Foreman Of Works reported on 3 July 1946 that the concrete blocks had been placed in position.

During the remainder of 1946 and in 1947 the bridge was kept under particularly close observation, and on 27 January 1948 (District Engineer's file 2443/55) the Foreman of Works reported:

I think that if anything the creek bed is higher now than when the concrete blocks were placed in position and the blocks have not sunk at all. Between piers Nos. 4 and 5 there is practically no water and sand is banked well up round these piers except No. 4's river side where the main channel now flows. The concrete blocks here are well out of the water and scour can be rated as nil since last inspected.

From then until 24 December 1953 there is no record of damage.

GENERAL METHOD OF INSPECTION OF BRIDGES AND PARTICULAR INSPECTIONS OF BRIDGE No 136

The Way and Works Branch of the Railways Department is divided into districts, each controlled by a District Engineer who is responsible to the Chief Civil Engineer for maintaining the track and bridges in his District in satisfactory condition.

The bridge over the Whangaehu River near Tangiwai is in the district controlled by the District Engineer, Wanganui (Mr H. G. Stevens).

His staff which is in any way concerned with the inspection of bridges is:

(1) The Works staff.

(2) The Permanent Way staff.

THE WORKS STAFF

The Works staff are the tradesmen and their helpers. They are controlled by a Foreman of Works, who is allocated a particular section of the district. The bridge is on the section of the Foreman of Works, Ohakune (Mr Rollerson). He is assisted by a Bridge Inspector (Mr W. F. Rollinson), whose main duty is to inspect the bridges.

THE PERMANENT WAY STAFF

The track in the district is also divided into sections under the control of Inspectors of Permanent Way. They control the line gangs, and their sections are further divided into gang lengths, each in the charge of a Ganger. The Ganger is responsible for the daily inspection of his length, which includes the cursory inspection of bridges and watercourses.

Inspections or observations of bridges are made as follows:

(1) By the Inspecting Engineer.

(2) By the District Engineer.

(3) By the Foreman of Works.

(4) By the Bridge Inspector.

(5) By the Inspector Permanent Way-

(*a*) on trolley

(*b*) on foot

(*c*) on engine

(6) By the length Gangers or by their deputies.

(7) By the Hallade record.

This list is arranged in the most convenient order to describe them but does not indicate their importance. The most important and detailed inspection is that carried out by the Bridge Inspector.

(1) Inspecting Engineer

He endeavours to carry out an inspection of all lines in company with the District Engineer, the Foreman of Works, and the Inspector Permanent Way every three or four years. He examines the bridge reports of all bridges, inspects the bridges, and where necessary, discusses what repairs or renewals should be made.

His last inspection of bridge No. 136 was made on 21 February 1953, and his comments were of a minor nature.

(2) District Engineer

His responsibility is set out in Section 164A of the Engineers' Code, which is as follows:

District Civil Engineers must arrange with Foremen for complete detailed inspection of all bridges at suitable intervals and must satisfy themselves by personal examination that bridge inspection is being made and reported upon in an efficient manner and that authorized repairs are being carried out promptly.

They must also, at suitable intervals, direct Foremen regarding authorized repairs and renewals, and must confirm in writing as soon as practicable all verbal instructions given to the Foreman concerning work to be done on bridges.

His last personal examination of Bridge No. 136 was made on 29 October 1953, and he was satisfied with its condition.

(3) and (4) Foreman of Works and Bridge Inspector

The responsibility and duty of Foreman of Works and Bridge Inspectors in regard to bridges is set out in Sections 14, 15, and 16 of the Inspectors' Code, and the instructions which have direct bearing on Bridge No. 136 are as follows:

Section 14: A Bridge Inspector must inspect in rotation all bridges and culverts in his district, such inspections to be made as frequently as the Foreman directs.

The Bridge Inspector must make himself familiar with the details of the various bridges in his district and must know the functions of the various members in the different types of bridges subject to his inspection. When inspecting he must give special attention to those parts that principally affect the safety of the bridge and traffic.

Masonry and concrete piers, abutments, or large concrete culverts must be examined for new cracks, settlements, increase of old defects or scouring around the foundations.

. . . . . .

The Foreman of Works will direct the Bridge Inspector when a detailed complete inspection of the bridge is again required.

. . . . . .

The Bridge Inspector shall observe the action of the structure when traversed by trains at schedule speed.

Section 16: In addition to the immediate report of serious defects which he finds in any bridge, a Bridge Inspector shall state in his four-weekly report to the Foreman the condition of the various bridges and cattlestops inspected during the period. These reports must be sent on by the Foreman to the Engineer, but where a complete detailed inspection of any bridge has been made, a separate complete report on such bridge must be made.

All defects found must be noted in this report. For convenience in filing, only one bridge should be dealt with in any such report.

In addition to the special detailed inspection of bridges the Bridge Inspector makes a general inspection of each bridge on the average of once every two to three months, when general conditions are noted.

His last detailed inspection was made on 22 May 1953, and the last general inspection 17 December 1953. Nothing of moment was disclosed.

(5) Inspector Permanent Way

Section 4 of the Inspectors' Code states:

Inspectors must make frequent personal inspections of their districts, either by trolley, velocipede or on foot and see that the line is safe and efficient condition.

. . . . . .

They must travel over the whole of their districts on the locomotives of the fastest scheduled trains running over each section, such trips to be made at least once every two months. Once every six months the Inspector must closely inspect each length accompanied by the Ganger.

The Inspector Permanent Way, Ohakune (Mr F. W. Beccard), carried out the following inspections:

(a) By motor trolley on 26 November 1953, 3 December 1953, 16 December 1953.

(b) Walked the length and inspected it in company with the Ganger on 17 November 1953.

(c) Travelled from Waiouru to Ohakune on engine of Daylight Limited Express on 24 December 1953, passing over Bridge No. 136 at about 2.15 p.m.

On none of these occasions did he observe anything unusual at the bridge.

(6) Inspection by Line Gang

Rule 218 states:

Unless special instructions to the contrary are issued by the District Engineer, each length must be carefully inspected each week day, on foot or by velocipede, by the Ganger, or he may specially appoint one or more trustworthy and experienced men of his gang to do this duty. The Ganger must satisfy himself that the inspection by his men is properly done and report any instance of neglect.

Once in each week he must personally inspect the whole of the length under his charge.

Unless special instructions are issued, lengths are not to be specially inspected on Sundays.

The last daily inspection of the length by the line gang was made on the afternoon of 24 December 1953, and the last weekly inspection by the Ganger was made on 19 December 1953.

Rule 219 states:

When there is any likelihood of damage to or obstruction of the line as the result of storm, floods, or earthquakes, or from any other cause, Gangers must arrange for such inspections as may be considered necessary, and must take such steps as may be required to safeguard the passage of trains; surface-men must take any action they may consider necessary to meet exceptional circumstances.

The weather was fine on the evening of 24 December 1953 and would not warn the Ganger that extra vigilance was necessary.

A copy of the Workmen's Code was produced (Exhibit No. 29), and this defines in detail the duties of a Ganger regarding bridges.

(7) The Hallade Record

This machine is a Continental development and is used by many railway systems.

It is mounted in a special car and is hauled at the rear of the fastest train over the section being tested.

Briefly, it consists of a series of pendulums and records separately the vertical, lateral, and rolling movements of the car. The record is produced on a continuous chart and provides a reliable indication of track irregularities by recording their effect on the movements of the car.

The Hallade was run northwards over the Main Trunk on the Limited Express on 3 November 1953, and southward by the corresponding express on 11 November 1953.

The record over Bridge No. 136 shows nothing unusual.

DAMAGE TO BRIDGE

The following damage to the bridge on 24 December 1953 was recorded by witnesses:

PIERS

Pier No. 2 had the top portion broken off, and this was lying under the bridge between Piers 1 and 2.

Pier No. 3 was smashed above the base into at least four pieces. Two pieces were found near the locomotive, one between Piers 2 and 3, but the remaining portion has not been found. Pier No.4 was removed bodily and broke into three pieces. The base portion, weighing about 126 tons, came to rest 70 yards downstream. The centre portion was found 300 yards downstream, but the top portion has not been located. Pier No. 5 was removed bodily and broke into at least two pieces. The top portion was found 50 yards downstream, but the lower portion has not been located.

Piers 1, 6, 7, and 8 were not damaged.

SPANS

Span No. 1 (22 ft. plate girders): This span was dislodged and the south end was thrown upstream.

Span No. 2 (44 ft. plate girders): This span was lying alongside the engine.

Span No. 3 (44 ft. plate girders): This span was on the right bank of the river about 80 yards downstream, immediately downstream of and lying beside Car A. 1907.

Spans No. 4 and 5 (both 22 ft. plate girders): One span was lying on the left bank near the bridge and the other has not been located. Spans 6 and 7 remained in place.

RECONSTRUCTION OF EVENTS

Much of the evidence submitted relating to the order of events at the crucial time of the destruction of the bridge and of the train and of the conditions about the bridge, including the bed of the river, rests on inferences on which the Board is asked to make findings of fact.

It seems unavoidable that the reconstruction of some events and circumstances must rest on such a foundation, but the Board has been careful since negligence is alleged to have regard to the cogency of such evidence.

The relative positions of the 44 ft. girder (span 3) and the first car (A. 1907) dictate that the girder was removed before the passage of the first car. This girder must therefore have been removed either before the locomotive arrived on the span or during the passage of the locomotive and tender over the span. If this girder was removed during the passage of the locomotive, there is a strong inference that some part of the heavy structure of the locomotive would have hit girder No. 2. There is, however, no evidence of extensive damage to girder No. 2, and it may therefore be inferred that girder No. 3 was not removed during the passage of the locomotive across it. Span 3 was therefore carried away before the locomotive entered upon it and there is a strong inference that Pier No. 4 was carried away before the train passed over it. This would also cause span 4 to be carried away.

There is also a strong inference that Pier 4 was removed by the lahar and that this caused the accident. The removal of Pier 5 at a later stage was partially a result, not a cause of the accident.

DESIGN OF THE BRIDGE

Most of the technical evidence alleged that the arrangement of the spans was not good and that by present-day standards the piers were not sufficiently deeply founded. It was also alleged that Piers 5 and 7 need not have been included in the original design and they unnecessarily obstructed the waterway. It is not sufficient, however, to show that their provision unnecessarily obstructed the waterway; it is necessary to show that the provision of these piers endangered the safety of the bridge during a flood which could reasonably have been expected. For this reason it has been necessary to call an expert witness to give an objective review of the methods of flood estimation. Unfortunately, the original design data were destroyed in the fire in the Hope Gibbons Building, but it was asserted, and not seriously challenged, that the estimation of the waterway would be based upon the Dun table, and that this would give a flow of 15,000 cusecs. It has been argued that this is an underestimate and the design figure should have been between 20,000 and 50,000 cusecs. These estimates were largely based on conjecture.

Mr F. M. Henderson, an expert witness before the Board, expressed the opinion that 20,000 cusecs, while appropriate to the "rational" method, should, on account of the pumice overlay, be modified. The view of the Board is that 15,000 cusecs is a reasonable estimate of the design rainfall flood.

Up to cut water level the area provided is 1,200 square feet, and the Board considers this to be an adequate design figure.

The Board accepts the view of Mr Turner that the waterway, the type of piers, and the type and length of the spans were adequate for a design rainfall flood of 15,000 cusecs.

FORECASTING OF LAHAR

A review by Mr James Healy of publications dealing with historical and technical matters relative to lahars or floods is attached hereto as Appendix I.

The first of the lists therein makes reference to lahars that occurred in the National Park area in previous times, though not necessarily down the Whangaehu River. The dates quoted are the years in which the articles were published. The references for 1931, 1933, 1934, 1944, 1952, and 1953 are to prehistoric lahars that originated during earlier and more active cycles of Ruapehu's eruptive history. Most of them are different entirely in character to the most recent lahar down the Whangaehu in 1953. They were mostly much more extensive laterally, and associated with violent volcanic activity current at the time. They are believed to have occurred before the present crater lake came into existence on Ruapehu.

The second list contains the references to historic floods down the Whangaehu River, and the dates quoted at the head of each section are the years in which the floods are believed to have occurred.

Several witnesses and counsel submitted that civil engineers should have possessed, first, knowledge of the source, and, second, an appreciation of what might happen, and that if these two facts were known to those concerned in the construction of this bridge in 1906 the bridge was not properly built even by standards of that time.

The Board in considering these submissions has had regard to the fact that a civil engineer to discharge his duties completely must not only know the source of a danger, but must also reasonably be able to make a quantitative assessment in order to design against it.

Quantitative information of flow is available only for the 1925 and 1953 lahars. The 1925 flow was approximately 15,000 cusecs, and the 1953 flow was affected by the 1945-46 eruption.

It has also had regard to the opinion of Mr Healy:

(*a*) That the rate of flow from, rather than the amount of water stored in, the crater lake determines the intensity of a lahar.

(*b*) That the rate of flow from the lake is largely governed by the size of the outlet.

(*c*) That the size of the outlet immediately following the lahar of 24 December 1953 was larger than had ever been noted before.

The intensity of past lahars provided no evidence that 15,000 cusecs was not a reasonable estimate for the design flood.

The Board therefore finds:

(i) That failure to design Bridge No. 136 specifically to withstand the destructive effects of a lahar of the type which destroyed it on 24 December 1953 was not due to lack of reasonable care.

(ii) That the engineers were in no position to assess from past experience the intensity of this lahar.

FAILURE OF PIER 4

The manner of failure of Pier 4 has been the subject of much conflicting evidence, and theories have been advanced to show that it failed by scour beneath the foundations, by overturning, and by bodily removal with and without "incipient scour" and "bed enlivenment". It was also alleged that its failure was due to lack of reasonable care in maintaining the bridge. The Board has given most careful consideration to the manner of failure of Pier 4, and to the question of whether the impact of the lahar would alone have caused failure of a well constructed and maintained pier.

Mr Turner stated that "the effective weight or density of the fluid would be substantially greater than that of water and that in combination with its considerable depth at the bridge site would exert considerable lateral load on the river bed and bridge piers".

Mr Healy considered that Pier 4 was removed bodily, and he submitted details of experiments carried out to determine the density of the flood.

Mr Healy's scientific training and instincts led him to submit fresh evidence in the course of which he mentioned further experiments to determine the density. His original estimate for the density was 1.6, but as the result of his further experiments he stated: "Although we might have to bring our maximum density down to 1.4 we still have no clear idea as to what maximum density would be".

When questioned further by Mr Hardie Boys, Mr Healy stated: "I think it was more than that, on the evidence of the boulders sitting up, but we will say the minimum was 1.4".

Mr Healy is the only witness who has made a quantitative determination of density. His opinion must be respected. The Board supports his view that the density was more than 1.4 "on the evidence of the boulders sitting up". The Board can make no quantitative assessment of the density, but evidence of heavy solids "sitting up" or, to be more precise, deposited a considerable height above the bed of the river, enables it to form a qualitative assessment that the density was extremely high.

But the Board has been more concerned with transporting capacity than with an accurate determination of the density. The main frame of car A. 1920 was found one and a half miles downstream, and there is a strong inference that its body was torn off early in its passage; span 3, consisting of two steel girders connected by open bracing and therefore having no buoyancy as a structure, was carried 100 yards downstream and left on the bank almost completely out of the water; 125 tons of Pier 4 was carried 70 yards downstream and left with its centre of gravity 6 ft. higher than it was originally; these items alone afford evidence of the great forces operating at the height of the lahar.

Mr Henderson stated that "Pier 4 was subject to the most severe effects of the flood" and also that "in the initial stages of the lahar it was likely that waves hit the upstream girders of span 3". The Board has therefore examined closely the high water levels on the northern bank and on Piers 6 and 7. Some of these levels are higher than the underside of the girders in span 3, and the Board is of the opinion that waves hit the upstream girder of span 3 in the early stages of the lahar. Lateral and diagonal forces on the pier then caused it to fracture at a construction joint, and the upper portion was then forced upwards and sideways. When the lower portion of the pier was relieved of most, if not all, of the vertical forces from above it was swept away by the flood. The upper portion of the pier and spans 3 and 4 were then unsupported and quickly followed.

The differential behaviour of Piers 3 and 4 supports this opinion. Pier 3 was not subjected to the not inconsiderable impact forces of a locomotive hitting it. These forces shattered the top portion of the pier down to the foundation block level and must surely have loosened the foundation. If scour was the fundamental cause of failure, then this block, which was fully submerged in a fluid of high density, would have been removed.

The Board therefore considers that the unpredictable forces of the lahar were of such nature and magnitude as to cause failure of a soundly constructed and maintained bridge.

In view of the allegations of negligence in the maintenance of the bridge after the 1925 damage, it is appropriate to record that Mr Turner stated:

> It is very difficult for me to get myself away from the present situation. I think, if I were an engineer and had advice of damage something like this, my main point would be to get the thing fixed up, and then I would express my surprise that there was no rain anywhere in the catchment, and I would make some inquiries; but I might not follow that further. On the other hand, if there were a series I would; but with one, so long as I could fix up the damage fairly readily, I don't think I would necessarily be unduly perturbed about it.

It is also of interest to record that Mr Howell, a responsible and competent engineer, who was in charge of the repair work following this flood, reported to the Chief Civil Engineer: "I do not anticipate any further trouble at this bridge".

After close consideration of the evidence the Board finds:

(1) That the repair work of 1925 was carefully and competently executed.

(2) That the then Chief Civil Engineer could reasonably take the view that this bridge would give no further trouble.

(3) That submissions that 1925 was the significant time spring largely from wisdom after the event.

During the period of the 1945-46 eruption the District Engineer's file shows evidence of vigilance, and on 3 July 1946 the Foreman of Works reported that eight 5-ton blocks had been placed in position around Pier 4.

When Mr Henderson was asked to comment upon the adequacy of these blocks, and after seeing the plan showing their disposition, he replied:

> Well, all I can say, sir, is if they were laid hard up against the pier as shown on this drawing, they should have afforded pretty good protection. I am surprised they were torn away.

The Hallade record reveals no irregularity in running over the bridge.

The Board considers that the behaviour of the bridge under traffic is a reasonable criterion of its safety and that observations of line and level of the track are significant. The Board is further convinced that since Mr Stevens assumed the duties of District Engineer, Wanganui, the maintenance of Bridge No. 136 has been of a high standard. Mr Stevens' evidence was clear and frank and he left the Board in no doubt that he is an able, competent, and conscientious District Engineer. His evidence also showed that on taking over the district he adopted a critical mind regarding the adequacy of Bridge No. 136, and he made sustained efforts to learn the nature of the foundation of Pier 4. The exhibit submitted of repair work carried out on Pier 5 is evidence of a good standard of workmanship. The Board finds that the failure of Bridge No. 136 was not in any way due to lack of reasonable care.

At this stage of the report it is appropriate to record that in respect of every member of the train crew of train No. 626 and of every member of the Way and Works and Traffic Branches whose duties can be regarded as being involved in the accident there has been no failure to exercise reasonable care or fulfil any duty or responsibility reasonably to be expected of that member in the circumstances leading to the accident. The Board thinks this view can properly apply also to Constable Smidt.

The Driver and Fireman lost their lives in the performance of their duties.

Since the accident the Guard, William Ian Inglis, has with other gallant persons been decorated by Her Majesty the Queen for his gallant conduct.

The Board also wishes to record that the evidence establishes that until the disaster occurred in train No. 626 had been regularly examined and tested and was normally and efficiently proceeding on its journey.

It is now necessary to consider the questions asked in the order of reference, which are as follows:

(1) *What was the cause of the accident?*

That question can shortly be disposed of in the finding that the accident was caused by the sudden release from the Crater Lake on Mount Ruapehu through an outlet cave beneath the Whangaehu Glacier of a huge mass of water which was channelled down the Whangaehu River carrying with it a high content of ash from the 1945 eruption and blocks of ice due to the collapse of large volumes of the glacier. This flood, which can properly be termed a "lahar", proceeded down the mountain as a wave, uplifting huge quantities of sand, silt, and boulders. It was most violent and turbulent and of great destructive effect. It destroyed portion of the railway bridge at Tangiwai before the arrival of train No. 626, which was engulfed when proceeding across the bridge.

(2) *Whether at any material time or times any person in the service of the New Zealand Government failed to exercise reasonable care or to fulfil any duty or responsibility reasonably to be expected of him in relation to the circumstances leading to the accident.*

The answer to that question is, No.

(3) *Generally, to inquire into and report upon such other matters arising out of the accident as may come to its notice in the course of its investigations and which it considers should be investigated and upon any matter affecting the premises which it considers should be brought to the Minister's attention.*

The following matters are referred to:

(i) During the hearing the suggestion was made by a professional witness with prior experience in the Railways Department that a Bridge Division should be created within the Chief Engineer's organisation to deal with the design, erection, and maintenance of railway bridges. This matter was not fully argued before the Board, but it appears that overseas such a provision is a common one and has advantages.

The Board commends such a suggestion for consideration.

(ii) During the course of the inquiry the question of emergency equipment on the train was raised. Generally, the provision made in the Guard's van can be regarded as sufficient, but in respect to emergency lighting the Board considers that in addition to the two kerosene and two hurricane lamps with a tin of fuel normally carried in the van there should be provided supplies of floodlights. These could be plugged in at points provided in each individual carriage, operating off the battery equipment in each case.

(iii) During the hearing the Board has received many letters recommending or advising on the design and structure of the new bridge which will be required over the Whangaehu River. The Board appreciates the goodwill and assistance of the writers, but feels that such matters involve many technical questions in which general design, siting, training works, and testing with models must receive due consideration.

Doubtless the facts of this disaster and the evidence adduced before the Board and the conclusions reached in this report will be properly weighed as the new bridge is considered. Meantime it can be asserted that the Board is satisfied that a new bridge can be designed to provide a safe structure with either one or three spans.

(4) *What steps (if any) should be taken to prevent a similar accident?*

Within a few days of the accident suggestions and recommendations were sent in by the public of New Zealand to the Prime Minister, to the Minister of Railways, to the General Manager, to the Secretary of the Board, and others outlining proposals for avoiding similar happenings in the future. Such widespread interest was evinced in the tragedy that many suggestions came from overseas.

Those making these recommendations have gone to considerable trouble in putting forward their views, which have been suitably acknowledged. All of the proposals have been carefully considered by the Board. They were referred to the Chief Civil Engineer of the Railways Department for investigation and report, and the conclusions of the Board are put forward after a full consideration of the views of the Department.

The proposals have been classified into five groups. Group (1) comprises suggested devices which include a float or ball-cock to operate a warning system when maximum flood level is reached. A large number of ideas come under this category, but only four are stated for installation upstream from the bridge. The Board agrees with the departmental view that floats and ball-cock devices are not suitable for operation in a flood with a high content of solid matter such as occurred on 24 December 1953. Moreover, any warning device attached to the bridge could fail in its purpose if the warning were given when the train was at or near the bridge.

Under Group (2) there were put forward devices (exclusive of floats or ball-cocks) for attachment to the bridge to operate a warning system when maximum flood level is reached or when there is movement in or collapse of the bridge piers or the bridge superstructure. As they are attachments to the bridge they could therefore fail in their purpose if the warning were given when the train was at or near the bridge. In the opinion of the Board any device relying on movement or collapse of the bridge piers or superstructure is not considered suitable. There is considerable vibration in a bridge under load at speed, and a bridge could be in a dangerous condition without any actual movement or collapse.

Dealing under Groups (3) and (4) with suggested devices to be placed upstream from the bridge to operate as a warning, it would appear that the idea of operation upstream is sound, but in the opinion of the Department none of those actually suggested is suitable. Some are too general or indefinite.

During the course of the hearing several worthwhile suggestions were put forward. The installation of a warning device in the gorge six or seven miles above the bridge on the principle of an activating force is being investigated by the Railways Department. Another device under consideration is one involving the use of an infra-red ray which would strike on the other side a photo-electric cell. Any obstruction would allow the contact to drop and so break it and give warning.

One expert witness stated that a warning device could be installed in the Whangaehu River at a convenient point along the Desert Road; while another suggested that some attention should be given to Crater Lake with the idea of destroying or deflecting the flood energy before it reaches the bridge or to give adequate warning in the event of a similar outburst.

Since Mount Ruapehu is not an extinct volcano it would not be prudent to assume that the contents of Crater Lake will always flow down the Whangaehu River. Accordingly it is recommended that warning devices should be installed at railway bridges over all streams between Waiouru and National Park.

Group (5) covers what may be termed the "miscellaneous" section. Many can be ruled out because of the high solid content of the flood waters, if for no other reason. Some contain ideas of value. Several persons have suggested shifting the present Tangiwai Station to a position nearer the bridge or have staff stationed at the bridge. Others again advocate a tunnel under the river, but even if a tunnel were practicable its cost would be of a very high order.

Due to technical and other problems the placing of the luggage and postal vans next to the engine is not considered feasible by the Department, and the Board upholds this contention. Although it would appear to be a simple matter to record the names and addresses of all passengers travelling on long-distance trains, this would not entirely be practicable, and in some cases could be unreliable. In regard to suggestions as to windows which can be opened instantly, it appears that the older type of quick drop windows was most difficult to keep weather and smoke proof. The more modern type was introduced, moreover, due to the proneness of children and youths to open the window to its full extent and lean out to their own danger. The type of glass now used is toughened and, when broken, does not sliver.

The provision of emergency exits in the roof of the carriages would mean a major change in the structural design, and there would be difficulty in keeping these weatherproof. They would need to be so tightly locked that it would possibly be more difficult to open the exit than to smash one of the carriage windows. Again, in the event of the carriage standing upright this exit could be a danger in electrified areas.

In the opinion of the Board the merits of shifting Tangiwai Station should be more fully considered in relation to other measures which may finally be adopted for ensuring future safety at the river crossing. The Board also considers that the condition of Crater Lake should be examined and reported on at regular intervals. Meanwhile it is appropriate to report that protective measures operate at present. These consist of:

(*a*) A telephone at the bridge site.

(*b*) The speed of all trains over the bridge is reduced to 6 miles an hour.

(*c*) A man is stationed at the bridge and drivers must not proceed unless they receive an "all clear" signal. It is understood that this patrol will be maintained until other effective warning measures are operative.

Counsel assisting the Board has in his final address mentioned that while witnesses have emphasized the need for the closest watch being kept on the level of the Crater Lake and the condition of its outlet there are wider implications arising from the increasing knowledge of the dangers inherent in the presence of so large a volume of water at such a high level. He suggests that moneys from the Earthquake and Disaster Funds might be made available to increase research into the characteristics of thermal activity in the mountain. This aspect we commend for consideration, though it is realised it must inevitably be embraced in the active programme of volcanic research which, according to recent information in the daily press, is now being undertaken.

CONCLUSION

The Board wishes to record the generous assistance it has received from counsel and advocates representing separate interests affected in these proceedings. Counsel appointed to assist the Board, Mr R. Hardie Boys, has been particularly helpful, while to the Secretary to the Board, Mr J. D. Murray, an officer of the New Zealand Railways Department, the Board is under a debt of gratitude for valuable assistance given most effectively and conscientiously.

The Board associates itself fully with the sentiments of sympathy extended by counsel and advocates to the relatives of those bereaved in this accident.

Dated at Wellington, this 23rd day of April 1954.

(Sgd.) W. F. STILWELL, Judge, Chairman.

(Sgd.) H. J. HOPKINS, Member.

(Sgd.) WILL APPLETON, Member.

SCHEDULE A

DETAILS OF STATEMENTS ADMITTED BY CONSENT AND DEPOSITIONS OF VARIOUS WITNESSES

	Reference to Evidence	
Name, Occupation, and Address	**Volume**	**Pages**
Barltrop, Clifton, Service Manager, Taumarunui	I	99-109
	I	140-142
Beccard, Frederick William, Inspector of Permanent Way, Railways, Ohakune	III	690-695
Bell, Arthur Dewar, Engineer, Ward Street, Raetihi (Statement submitted by Counsel)	I	232-234
Bentley, Donald, Engine-driver, Railways, Taihape	I	186-199
Bishop, Charles Thomas, Acting Chief Mechanical Engineer, Railways, Wellington	II	417-431
	IV	852-856
Brown, Williams John Kenneth, Inspector of Police, Wanganui	I	110-132
Bryan, John Herbert, Post and Telegraph Employee, Dannevirke	II	275-296
Bryden, Percival Benton, Research Engineer, Railways, Wellington	IV	791-851
Butcher, William Robert, District Mechanical Engineer, Railways, Auckland	II	432-454
Chapman, Daniel Miles, Public Passenger Transport Operator, Bulls	I	181-185
Diggle, Alfred Kirkman, Train Running Officer, Railways, Wellington	I	220-224
Dow, John, District Engineer, Railways, Auckland	III	727-760
Ellis, Arthur Cyril, Mail Clerk, Taihape	III	549-579
Ennis, Horace Heathcote, County Engineer, Raetihi	II	404-416
Evans, Albert Harrison, Casual Bridgeman, Railways, Rangataua	III	705-712
Evans, Allan, Transportation Superintendent, Railways, Wellington	I	31-37
	I	155-157
French, John Bernard, Fitter, Wellington	II	270-274
Gabites, John Fletcher, Meteorological Research Officer, Wellington	II	332-343
Hall, Raymond John, Station Agent, Railways, Tangiwai	I	77-87
Hanwright, William Thomas, Ganger, Railways, Rangataua	III	696-702
Harris, Roger Wilson, Chief Engineer, Rangitikei Catchment Board, Marton	II	359-402
Hartwell, Eric James, Engineer, Wanganui	I	235-247
Healy, James, Superintending Geologist, Rotorua	II	489-548
	III	642-652
	V	1255-1279
Henderson, Francis Martin, Senior Lecturer in Engineering, Canterbury University College	V	1129-1146
	1170	
Holman, John Warren, Compositor, Wellington	I	225-229
Hyde, William Julius, Retired Civil Engineer, Wellington	III	714-726
Ince, David Daniel, Retired Engineer, Wellington	V	1348-1355
Inglis, William Ian, Guard, Railways, Wellington	I	200-219
	I	261-262
Kyle, Edgar John, Stationmaster, Railways, Waiouru	I	158-166
Lusty, Horace Campbell, General Manager of Railways, Wellington	I	24-30
	I	143-154
Macallan, Ian, Consulting Engineer, Wellington	V	1149-1169
	V	1171-1206
Manhire, Stanley Clifford, Carpenter, Waiouru	I	38-44
Mercer, John Cubridge, Registered Medical Practitioner and Pathologist, Wellington (Statement submitted by counsel)	I	230-231

Name, Occupation, and Address	Reference to Evidence Volume	Pages
Morrison, Walter Gordon, Consulting Engineer, Wellington	V	1090-1128
Munster, Mrs Evelyn Isobel, Married, Wellington. (Statement Submitted by Counsel)	IV	857-858
Munster, Raymond John, Meteorologist, Wellington	I	263-269
Murison, Athol Huntly, Chief Civil Engineer, Railways, Wellington	III	580-641
	IV	859-884
Nelson, David, Registered Surveyor, Napier	II	482-488
Newnham, William Langston, Registered Civil Engineer, Wellington	IV	885-905
Pawson, Thomas Winton, Warrant Officer, New Zealand Army, Waiouru	I	173-180
Porter, James Paterson, Civil Engineer, Auckland	IV	912-1008
Prebble, Oswald Maynard, Secretary, Eastbourne	II	321-331
Purchase, Harry Zander, District Mechanical Engineer, Railways, Wellington	II	471-481
Ransfield, Hemi Matiaha, Guard’s Assistant, Railways, Palmerston North	I	255-260
Reid, Walter, Ganger, Railways, Tangiwai, (Statement submitted by counsel)	III	703-704
Rollinson, William Frank, Bridge Inspector, Railways, Ohakune	III	681-689
Sheffield, Roy, Physical Welfare Officer, Gisborne	II	344-358
Sim, Leo, Bridgebuilder, Auckland	II	455-470
Smidt, Leo Semper, Police Constable, Waiouru	I	45-61
Somerville, Robert, Post and Telegraph Employee, Wellington	I	133-139
Stephens, Niko, Farmer, Tangiwai	I	62-76
Stevens, Hubert Garibaldi, District Engineer, Railways, Wanganui	III	653-680
	III	761-790
	IV	907-911
	V	1207-1213
Sulenta, Drago, Carpenter, Auckland	I	248-254
Thompson, George Harrison, Toolmaker, Eastbourne	II	297-301
Turner, Charles William Oakey, Engineer-in-Chief, Ministry of Works, Wellington	V	1214-1254
Turton, Willis John, Head Guide, Chateau Tongariro	II	302-320
Wakelin, Gordon Edward, Engineering Worker, Taumarunui	I	88-98
Wildbore, Trevor Ernest, Clerk, Ohakune	I	167-172

SCHEDULE B

DETAILS OF EXHIBITS PRODUCED AT THE SITTINGS OF THE BOARD

Exhibit Letter or number	Description
A	Book of suggestions received from members of the public.
B	List of identified victims.
C	List of missing persons.
D	Photographs of unusual cloud formation. Mr J. B. French.
E	Sketch of cave in Crater Lake. Mr J. H. Bryan.
F	Photographs produced by Mr J. H. Bryan.
G	Photographs produced by Mr G. H. Thompson.
H	Photographs Produced by Mr W. J. Turton.
I	Photographs produced by Mr R. W. Harris.
J	Artist’s impression of moment of disaster, produced by Mr W. Julius Hyde.
K	Drawing “A”, produced by Mr W. Julius Hyde.
L	Drawing “B”, produced by Mr W. Julius Hyde.
M	Drawing of suggested new bridge. Mr W. Julius Hyde.
N	Sketch plan of bridge site. Mr J. P. Porter.

Exhibit Letter or number	Description
O	Semi-perspective elevation of bridge. Mr J. P. Porter.
P	Photographs of scene of disaster, produced by Mr J. P. Porter.
Q	Photograph of base of Pier 4, produced by Mr J. P. Porter.
R	Drawings concerning flood measurements, prepared by Mr R. W. Harris.
S	Plan No. 68100/15 as supplied to counsel prior to commencement of sittings.
T	Statement on forces operating at Pier 4, prepared by Mr J. P. Porter.
U	Preliminary estimate of maximum flood in Whangaehu for purposes of re-design of bridge. Mr J. P. Porter.
V	Drawing illustrating theory of failure of Pier 4, produced by Mr W. G. Morrison.
W	File of correspondence on Mount Ruapehu and Whangaehu River.
X	"Design of Waterway Areas for Bridges and Culverts", by C. B. McCullough.
1	Bound set of plans.
2 & 3	Bound collections of photographs.
4	Schedule of plans.
5	Schedule of photographs.
6	Envelope of photographs.
7	Working Timetable N.I.M.L. and B.
8	Wanganui Train Advice No. 2010.
9	Train Control Diagram, Palmerston North – Ohakune Junction.
10	Guard's Mis./7 for train No. 626 on 24 December 1953.
11	Table showing scheduled, actual, and minimum running times.
12	Mis./6A, Train Register, Waiouru.
13	Mis./6A, Train Register, Tangiwai.
14	Mis./6A, Train Register, Karioi.
15	Photograph of caravan, produced by Mr Ca. Barltrop.
16	Book of Rules and Regulations.
17	Return of passengers on No. 626 on 24 December 1953.
18	Details of service of No. 626 on 24 December 1953.
19	Photographs of bridge taken 4 December 1953 by Mr P. Barnes.
20	Photographs produced by Mr L. Sim.
21	Sketch plan of Mt Ruapehu.
22	Model of Mount Ruapehu.
23	Photographs produced by Mr J. Healy.
24	Further photograph produced by Mr J. Healy.
25	Further sketch plan produced by Mr J. Healy.
26	Contour map and three photographs of Mount Ruapehu.
27	Analyses of samples of water.
28	Letter from Mr L. S. Vause produced by Mr J. Healy.
29	Maintenance Codes.
30	List of lahars and floods prepared by Mr J. Healy.
31	File on Bridge No. 136 – District Engineer, Wanganui.
32	File on Bridge No. 136 – Foreman of Works, Ohakune.
33	Plan of Borings at Bridge No. 136.
34	Civil Engineering Branch Notes and Instructions.
35	Details of bridges (strength sheets), Te Koura – Taihape.
36	Plan showing analysis of stresses on Pier 4.
37	Sketch of flood warning device.
38	Hallade record.
39	File on Bridge No. 136 – Chief Civil Engineer.
40	Piece of concrete from Pier 5.
41	Longitudinal section and plan showing road and rail from 234m to 235m.
42	Reconstructed plan of Bridge No. 136 and scale drawing of locomotive and two cars.
43	Model of Whangaehu River Basin.
44	Bridge Information Sheet (Ministry of Works).
45	Bridge Sites – Surveys and Plans (Ministry of Works pamphlet).
46	Ministry of Works file on Mount Ruapehu and Whangaehu River.
47	Further photographs produced by Mr J. Healy.
48	Graph showing time of arrival of lahar at a number of places on Whangaehu River.

APPENDIX I

RUAPEHU LAHARS

1931: "Conical Hills on Egmont and Ruapehu Volcanoes," L. I. Grange.

N. Z. Jour. Sci. and Tech., Vol. 12, pp, 376-384.

"Early in March 1929 the writer reported to the Director of Geological Survey that he considered that the conical hills on Ruapehu were part of a mud-flow from the mountain" (p. 376).

(Page 382-383): "The writer maintains that both the west Egmont and the Ruapehu conical hills, and the under-lying agglomerates, are mud-flows caused either by eruption from a crater lake, collapse of a sector of a volcano, or by the action of rain and volcanic ash on the sides of the volcanoes during or following an eruption. Evidence for this belief is mainly this: historic mudflows on volcanoes display conical hills similar in all respects to those of Egmont and Ruapehu. On the debris that swept down the northern slope of Bandai-san at a speed estimated at 48 miles per hour, during the eruption of 15 July 1888, there were numerous conical hills which have been formed by the thermal disintegration of large boulders of andesite. Similar mounds were formed on the debris that moved across White Island crater in September 1914. Palmer in the Volcano Letter (No. 253, Oct. 1929) refers to the historic mudflows with hillocks on them in Java.

1933: "Tongariro District". L. I. Grange and J. H. Williamson. N.Z. Geological Survey, 27th Annual Report, pp. 18-21.

"Mudflows have swept down the slopes of Ruapehu. One that rushed down the north-western slopes extended a few miles beyond the National Park – Tokaanu Road and left numerous conical hills up to about 18ft. in height and composed of coarse agglomerate. The latest one came down the Whangaehu in 1869 and spread out on the flats immediately west of the Waiouru-Tokaanu Road without forming any conical hills".

(This referred to the 1861 mudflow.)

1934: "Report of the National Park Board: Geology of the Park." P. Marshall. Parl. Paper C-10, pp-. 3-4.

"Curious features are the conical hills at the junction of the Taupo and Chateau roads. These are relics of a phase of activity that has often been witnessed in Java and is there termed a *lahar*. From time to time the crater becomes filled with water, and as activity increases it is forced out of the crater, and, sweeping down the league-long slopes of the mountain, becomes a huge avalanche of rocks, stones, and water. Near the base of the mountain the velocity of the flow decreases and some of the larger rock masses come to rest. Other material collects around them, while the main mass of the lahar moves on. The parts left behind are the conical hills. They are similar in all respects to the 'thousand hills' of java, while in New Zealand they may be counted in hundreds, reaching up the lower slopes of Egmont from Parihaka."

1944: "Volcanoes as Landscape Forms." C. A. Cotton, 1944

On pages 239-253 lahars are classified and described, and numerous examples are quoted.

"In New Zealand an immense bouldery accumulation of volcanic conglomerate underlies the plains and low country westward and southward of the volcano Ruapehu. . . . A tongue of the conglomerate extends far south-eastward along the Hautapu valley. . . . The largest of these boulders that has been described is as distant at forty-eight miles from Ruapehu. It is stranded on the side of the wide valley of the Rangitikei River below the junction of the Hautapu, which is a tributary, and rests 16 feet above the lowest terrace, which is 175 ft. above the river. The block is 145 feet long, 6 feet wide, and 5.5 feet high, and has been estimated to weigh 37 tons. This block is well rounded, but is also deeply scored longitudinally and diagonally, very probably as the result of the continued passage of a lahar over it after it had come to rest. Quite naturally the striated surface has been claimed as a proof of glacial transport. It is unnecessary, however to assume a glacial origin for these conglomerates to account for the transport of large boulders, as it is known from observation of present-day lahars in Java that they have ample mobility and transporting power for the purpose. Melting of glaciers by avalanches of hot material from an adjacent crater may, however, have contributed much of the water for Ruapehu lahars. The absence of the angular blocks may also be explained without appealing to recent weathering in explanation of rounding, if the theory of glacial transport is rejected in favour of that of lahar origin."

"A miniature example of a mound-field landscape which was developed in 1914 by a mudflow on the small volcano White Island is shown in Fig. 131. ……… The origin of extensive mound fields near the bases of the New Zealand volcanic mountains Ruapehu and Egmont remained a mystery until the lahar explanation was invoked by Grange to account for them. The Ruapehu example, in the Tongariro National Park, is shown in Fig. 132, and an extensive landscape of mounds on the south-west side of the extinct volcano Egmont I n Fig. 133".

1945: Evening Post and Dominion, March 12

Professor Cotton flew over with Mr A. Prichard, pilot of Public Works Department. A member of Geological Survey flew with R.N.Z.A.F. a day or two before. A part of the article referred to the 1895 eruption. "On March 10, 1895, there was an enormous discharge of boiling water from the alpine geyser, and a wonderful cloud show followed on a bright, clear morning, with steam rising 6,000 ft., visible for many miles around. Near the mountain a great roaring was heard, and there was a continuous earth tremor. Streams of geyser and melted snow water poured down the glacier and flooded the Whangaehu River and lesser streams. That show ranked as one of the great geyser displays the world over."

The *Evening Post,* 24 March 1945

Reported that an officer of Geological Survey flew from Wellington. Professor Cotton commented on changes of activity. The article continued, the source of the information not stated:

"Though Ruapehu's greater activity is lively it is still far from being of eruptive violence, but when great volumes of steam rush upward in such a crater there are always possibilities of secondary effects. The crater is a great bowl, a mile or so across, 500 to 1,000 feet deep, and more or less filled with ice, except for the central lake. If the steam melts a great part of this ice Ruapehu will hold a huge mass of water, 5,000 feet in the air, and held by ragged and perhaps rifted rock walls – the conditions which may lead to a 'lahar' when the melted ice water breaks through a rift in the crater wall and pours down the mountain side, carrying rocks, boulders, and sand. Normally the crater lake discharges into the Whangaehu River, which is always discoloured but in the distant past there have been great 'lahar' overflows, of which there are clear indications about Taihape, and even as far as Mangaweka, 40 miles south of the mountain.

"So far nothing approaching the lahar condition has yet developed, and there is no sign of any new

The New Zealand Observer. (Undated, about April 1945)

Article by C. W. Carrick, in which Cotton was interviewed (Prof. C. A. Cotton), and stated:

"The island that has appeared in the crater lake may be the beginning of a new cone, or it may be the lake bottom pushing up from below. Whatever it is, there is probably a dome-shaped mass of lava rising underneath. That might do anything. It might stop where it is, or it might explode – but not violently. Or," he went on, "it might push part of the existing crater wall down, and start to flow down the side of the mountain. Even if it did so, it would probably belch over the eastern side towards the Desert Road, and there is plenty of room for it there.

In the same article lahars are discussed, with quotations from Cotton's book on Volcanoes. The article states:

"Professor Cotton has described the effect of its 'lahars', or mudflows, which can be traced for many miles. Great fields of irregular mounds in the National Park area are identified by geologists as lahars. South of the mountain, the mudflows carried enormous boulders as far as the present site of Taihape . . . Professor Cotton thinks the new island in Ruapehu's lake is like the island on Keloet, a stiff mass thrust up from below, and as likely as not to peter out.

Evening Post, 2 July 1945

Article on Cotton's paper on Ruapehu in 1945, published in the *New Zealand Science Review.*

New Zealand Science Revue, Vol. 3, No. 1, May 1945, pp. 3-4, by Professor C. A. Cotton.

"Some very active volcanoes that are in the habit of thrusting up large tholoids so as to choke their craters – Pelee, in Martinique, and Merapi, in Java, for example – get rid of them again by explosion. The tholoids disintegrate explosively as gas that has remained in the still-hot lava is disengaged; and glowing avalanches consisting of lava dust and red-hot fragments still emitting gas rush down the mountain-sides with terrific velocity and sometimes with very disastrous results.

"Frequently in Java crater lakes similar to that of Ruapehu have broken their banks during eruption and the resulting floods have swept down bouldery debris as 'hot lahars' for many miles. Such an outbreak from Keloet cost over 5,000 lives in 1919. The Keloet crater lake is about twice as large as that on Ruapehu. Vast quantities of boulders of Ruapehu andesite south-west-ward and southward of the mountain must have been transported thus by lahars in bygone ages. Perhaps Ruapehu will never again provide such spectacular and alarming displays of its activity as are afforded by great lahars and glowing avalanches. The mild eruption which has just now come to an end (or possibly only paused for breath) has been confined apparently to the exudation of a small tholoid, as already described the carapace of which was soon chilled and completely hardened in contact with the waters of the lake."

Footnote: "Activity similar to that of March commenced in May."

Wanganui Herald of 5 July 1945

The rescue party that climbed the mountain when R. L. Oliver was injured reported that the lake was now buried by volcanic debris and that debris might be ejected on to the Whangaehu glacier. The eruptions of August 1889 and March 1895 that caused floods down the Whangaehu were mentioned.

"Activity at Ruapehu, March-April 1945." J. J. Reed, Geological Survey.

N.Z. Journl. Sci. and Tech., Vol. 27, pp. 17-23.

"Water percolating through the eastern scoriaeceous wall probably forms the source of the Whangaehu River. Mudflows (lahars) from Ruapehu, accounting for the presence of mounded fields at the base of the volcano (Grange, 1931), have formed vast accumulations of volcanic conglomerate, large boulders being transported up to 48 miles (Cotton, 1944).

"Except for a mudflow, which apparently swept down the Whangaehu River in 1869 or earlier (Crawford, 1869, pp. 354; Cussen, 1887; Grange and Williamson, 1932-33), outbursts within historical records have been confined to the Crater Lake, the presence of which may mask to some extent the activity of Ruapehu." (A list of known eruptions follows).

1952: "The Geology of the Rangitikei Valley." M. T. Te Punga. *D.S.I.R. Geological Memoir No. 8.*

1953: "The Geology of the Wanganui Subdivision." C. A. Fleming. *N.Z. Geological Survey Bulletin No. 52.*

The above two publications describe and refer to lahar deposits derived from Ruapehu.

FLOODS IN WHANGAHU RIVER ORIGINATING ON MOUNT RUAPEHU

1861: "13 February, 6 a.m." *Richard Taylor's Journal.* (Typescript copy held in Turnbull Library.)

The flood lasted about 2 hr. A Maori who saw it described the surface as a thick mass of snow, ice, timber and rubbish of all kinds, reaching at the peak within at least 6 ft of the floor of the bridge near the coast.

Taylor also commented on the fact that piles seemed very short and was inclined to believe earlier charges that builders had not driven piles to the stipulated 6 ft.

The date 10 December 1859, given in R. Taylor's "Te Ika A Maui", 2nd Ed. 1870; 463-4 for this flood, is incorrect as his journal shows.

W. Skey, 1860, *Trans. N.Z. Inst 1* : 432, apparently referring to same flood, also gives wrong date as 1863.

J. C. Crawford, 1870, *Trans. N.Z. Inst. 2 :* 354 and 1880, "Recollections of Travel in N.Z. and Australia": 131, stated that an avalanche from top of Ruapehu piled up at major bend in Whangaehu and blocked it and that accumulated water broke through sweeping the debris downstream and destroying the bridge.

Crawford was in the Whangaehu Valley probably early in 1862, and saw "the ground had been bared and large patches of bush swept away".

This may have been the same flood referred to by Cussen, L., 1877, *Trans. N.Z. Inst. 19 :* 379-80. He stated that he had been informed that an abnormal flood had occurred in the Whangaehu 18 years before his paper was read in 1886.

1899 Year-Book referring to 1861 flood states that probably due to heating of mountain, the lake water was suddenly thrown over the adjoining icefields ……… (Article repeated in 1900 Year-Book.)

But both theories are speculative as the existence of crater lake was not known in 1861 and the mountain not climbed till 1877.

1889: 1 May. Abnormal flood in Whangaehu water rising 3-4 ft. within a few minutes. Associated with eruptions from Ruapehu at 11 a.m. and 12 p.m. Witnessed from Lake Taupo. H. Hill, 1892, *Trans N.Z. Inst. 24 :* 619-20. Date given by Hill, 1891, *A'asian Ass. Adv. Sci. 3 :* 171 is August, but he former date is based on telegram reporting the eruptions.

Hill in both papers and also in *N.Z. Alpine Journal 2* (8), 1895, 79, states that in March 1890 debris and boulders of blue mud were met with along the north and north-east of the snowfield for 50 yards from the crater. He suggested that the lake water had welled over the lip of the crater.

1895: 10 March. Abnormal flood in Whangaehu and discolouration of waters of Wanganui River. Lake waters thrown out during a violent eruption of steam and volcanic ash. J. Martin in Tongariro National Park, by J. Cowan, 1927. No evidence of the size of the flood.

W. H. Dunnage (in Ascent of Mount Ruapehu, Lands Dept. Ann. Rep. 1895, pp. 102-3) stated that on his visit on 5 April the lake was 10-12 ft. lower than on his visit at Easter 1894, exposing a beach ½1 chain wide on all sides but the east. Two photographs, one taken on 5 April 1895 and one at Easter, 1894, published with a report on Ruapehu by W. H. Dunnage in Lands Dept. Ann. Rep., 1895, show the change of lake level.

1925: Late Jan. *Evening Post*, 3 March, reporting flooding in Whangaehu and visit to crater. Cause of flooding thought to be blocking of cave by falloff ice. Water melted the ice.

1953: 24 December.

SUMMARY

Lahars have occurred in the Whangaehu in 1861, 1889, 1895, 1925, and 1953.

The floods of 1861, 1925, and 1953 appear to be cold lahars due to release of lake water below the glacier. Those of 1889 and 1895 resulted from eruptions in the crater lake.

The flooding appears to have been considerable on at least four occasions.