MIN-3848 Report on the failure of the SH35 Mangahauini Bridge

17 June 2022

Following your visit to the Tairāwhiti region in April 2022 to assess damage caused by the March 2022 weather event, you requested that a full report was compiled and provided to you on the failure of the State Highway 35 (SH35) Mangahauini Bridge near Tokomaru Bay.

- MIN-3868, which contained the high-level findings of WSP, was provided to you on 6 May 2022. BRI-2445 contains details about the resilience programme for the region and contextual information relevant to the failure of the bridge.

- Please find attached a copy of *Mang No. 1 Abut Approach Failure R2 issued.pdf*, which sets out the investigation into the failure of the Mangahauini No.1 Bridge.

Project Number: 2-U3436.BM EM011

Mangahauini No. 1 Bridge, Tokomaru Bay

Abutment Approach Failure Investigations

13 June 2022

CONFIDENTIAL

Report No. U22/33

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Revision Details

Revision	Details
D1	Draft for peer review
R1	Issued to Waka Kotahi NZ Transport Agency
R2	Amended as requested by Waka Kotahi and reissued

Contents

Disclaimers and Limitations

This report '*Mangahauini No. 1 Bridge, Tokomaru Bay: Abutment Approach Failure Investigations*' ('**Report**') has been prepared by WSP exclusively for Waka Kotahi NZ Transport Agency ('**Client**') in relation to investigating the causes into the abutment failure at Mangahauini No. 1 Bridge at Tokomaru Bay in March 2022 ('**Purpose**') and in accordance with the Professional Services Contract NZTA 3436 Structures Management. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

Executive Summary

The southern abutment to Mangahauini No. 1 Bridge at Tokomaru Bay was washed out in the early hours of 23rd March 2022 during a storm event that commenced on the previous afternoon.

Waka Kotahi NZ Transport Agency received a ministerial enquiry stating that the Minister had "*heard from the team on the ground an initial indication that forestry slash was a significant contributor to the collapse of Mangahauini Bridge. The Minister would like to receive a report into the failure of the bridge that provides advice on any impact of debris and slash on the collapse.*"

WSP, as Waka Kotahi's Structures Management Consultant for the Gisborne region has investigated the abutment washout and believe there are several contributing causes including but not limited to:

- Debris build up on bridge;
- The size of the rainfall event;
- Lack of resilience in the network;
- Tidal effects;
- River alignment.

Having looked at each cause in turn, we believe that while all the above effects have contributed to the abutment washout, the three main causes, in no particular order, are the debris build up on the bridge, noting that at the site, some of the debris appeared to be general woody material rather than slash per se, the size of the rainfall event and the lack of resilience in the network. The two other effects of tide and river alignment has lesser consequence but nonetheless are contributary factors.

1 Introduction

Mangahauini No. 1 Bridge, built in 1967 is located on SH35 (Waiapu Road) at Tokomaru Bay and comprises a reinforced concrete structure with 6 x 13.7m spans. As-built drawings show the river flowed reasonably evenly under the four central spans at the time of construction. The southern (Gisborne end) abutment was constructed over a sand bank, see Figure 1-1 below.

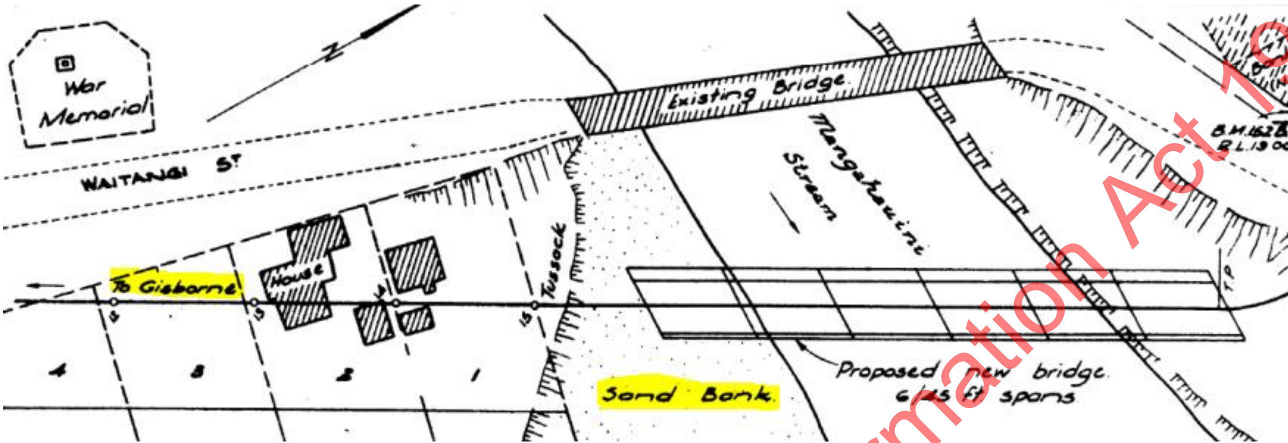


Figure 1-1 : Snip from as-built drawings showing plan of Mangahauini No. 1 Bridge

Early on the morning of 23rd March following heavy and prolonged overnight rain, the southern abutment fill washed out; further rainfall caused the gap between the back of the abutment and the approach fill to widen.

Figure 1-2: Looking upstream, showing washed out abutment and gap to the road

Following a visit by Waka Kotahi with the Minister, where the impact of forestry debris and slash on the regions assets were discussed, Waka Kotahi received a ministerial enquiry stating that the minister "…. *had heard from the team on the ground an initial indication that forestry slash was a significant contributor to the collapse of Mangahauini Bridge. The Minister would like to receive a report into the failure of the bridge that provides advice on any impact of debris and slash on the collapse."*

This report investigates the causes of the bridge abutment washout. The following sections examine the factors that may have contributed to the abutment fill failing.

2 Debris Build-up on Bridge

WSP has examined photos of the debris and held discussion with others who were on the ground during the time of the recent March event and at an earlier event in June 2021.

Figure 2-1 below of the bridge looking northwards from just upstream of the failed southern abutment approach shows some debris in the channel upstream of the southern end span. You will notice that the debris comprises mostly of shrubs and other woody material that has not resulted from logged trees, but possibly trees that have fallen into the river as a result of the high flows. This is opposed to slash, which is the result of logged trees left on the slopes.

Figure 2-1 : Woody debris upstream of southern end span. (Failed abutment approach is at RHS)

Figure 2-2, photos showing a view of the far (northern) bank at the opposite end of the bridge does however indicate a significant amount of forestry type logging debris; the stockpile appears to have been removed from the northern spans adjacent to or on the true left bank of the river.

Figure 2-2: Logging type debris on left bank upstream of and at northern end of bridge

With the flow confined in recent times to the 3 southern spans (of 6 total) and with debris at the left bank and also blocking the southern end span, a significant extent of the waterway area (approx. a third) was lost. This would have appreciably contributed to the water finding an alternative path of lesser resistance, around the back of the abutment.

3 Size of Rainfall Event

Gisborne District Council (GDC) has provided rainfall records and estimates of Average Recurrence Interval (ARI) of the rainfall event which lasted for several days over the period 21st to 26th March 2022; this data has been provided for several sites in the east coast region. While GDC does not have a site at Tokomaru Bay, the data provided included that from Te Puia, which is the closest, being approx. 10km north of Tokomaru Bay. The catchment of the Mangahauini Stream is to the north of Tokomaru, draining an area of approx. 25km^2. Figure 3.1 shows the location of the telemetry stations for which GDC has provided data in relation to this storm event.

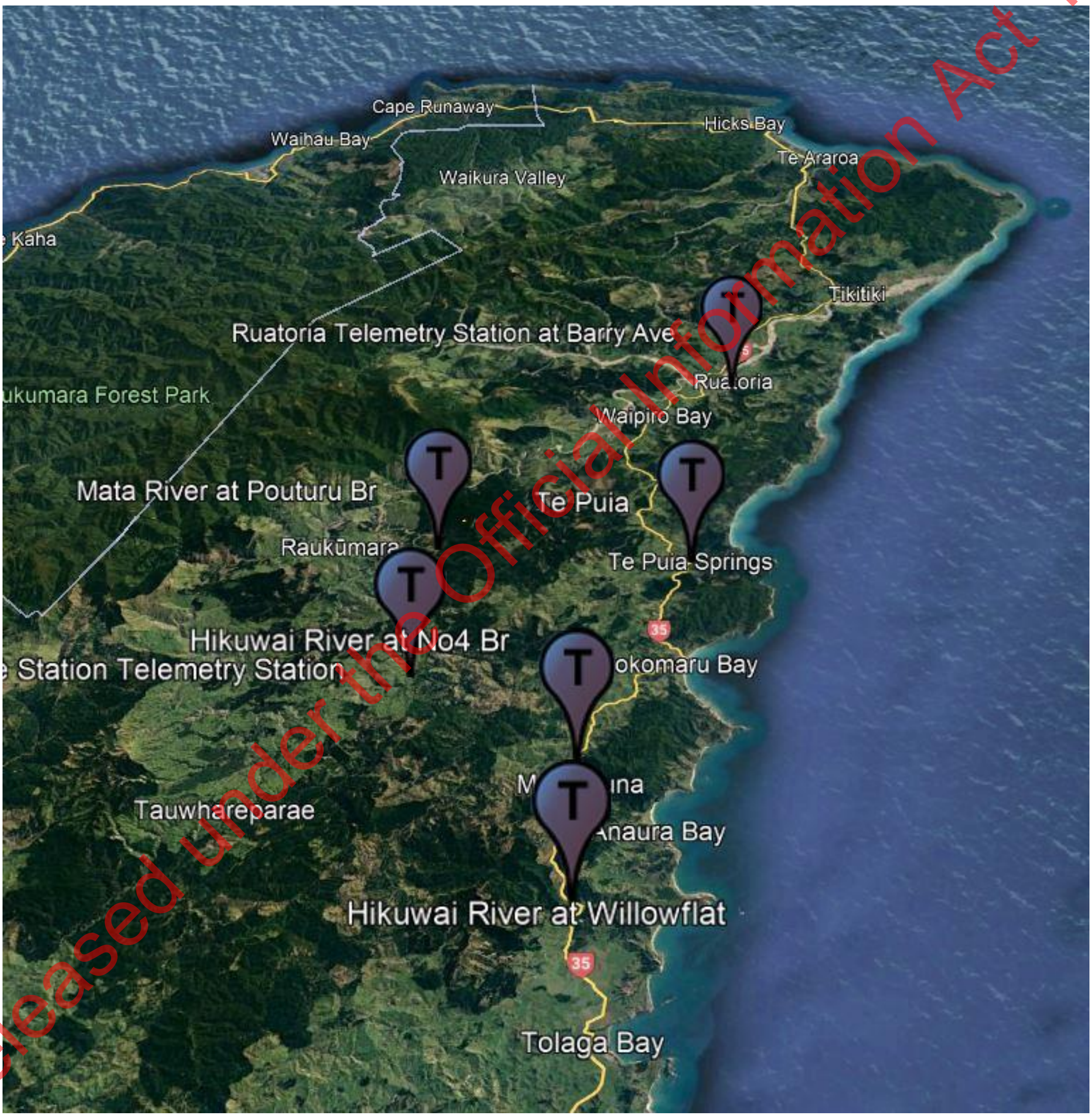


Fig 3-1: GDC Telemetry Stations around the Tokomaru Bay area (image from Google Earth)

An Average Recurrence Interval (ARI) (in years) has been obtained for the rainfall data (considering different durations) using the National Institute of Water and Atmospheric Research (NIWA)'s web-based programme, known as HIRDS (High Intensity Rainfall Design System) (version 4) (NIWA, 2017). Where rainfall did not exactly match the rainfall depth for a given ARI, interpolation was used to estimate the ARI of the recorded rainfall totals.

Different ARIs have been derived for different durations of rainfall ranging for 10 minutes to 5 days. During the event, for durations higher than 6 hours, the highest intensities were recorded at Te Puia. The maximum rainfall recorded at Te Puia over 6 hours was 236 mm; this has an ARI of over 100 years. Although the ARI is estimated to be over 200 years (using HIRDS), the uncertainties and limitations increase as the ARI becomes higher i.e , it can safely be said that the ARI at Te Puia was greater than 100 years, but because of the high ARI it is uncertain how much greater than 100 years the event might have been. An ARI of 100 years is a significant rainfall event.

Tables 3-1 and 3-2 below are highlighted in orange to show those with the highest rainfall intensities (where the ARI exceeds 50 years) during the rain event 21st – 26th March 2022. The results for the Te Puia site are circled below.

Table 3-1: Maximum rainfall depth recorded for different duration during March 2022 rain event

Site	Maximum rainfall depth (mm) recorded for different durations during event											
	10 min	20 min	30 min	1 hour	2 hour	6 hour	12 hour	1 day	2 day	3 day	4 day	5 day
Fernside Station Telemetry Station	10.8	17.0	26.2	38.2	49.6	94.8	112.0	193.2	264.0	355.2	369.0	375.8
Hikuwai River at No4 Br	19.0	28.0	34.0	60.0	106.0	160.0	203.0	296.0	377.0	435.5	441.0	445.0
Hikuwai River at Willowflat	14.5	22.5	30.5	51.5	80.5	133.0	190.5	246.0	349.5	437.0	445.5	452.5
Mata River at Pouturu Br	14.5	23.5	31.5	51.0	68.0	149.5	174.0	239.5	352.0	435.0	445.5	451.5
Ruatoria Telemetry Station at Barry Ave	13.5	24.5	28.5	42.0	76.0	96.0	124.0	177.0	241.0	313.5	316.0	316.0
Te Puia	15.5	28.0	36.5	63.0	95.5	236.0	277.5	346.5	432.5	528.5	531.0	533.0

Table 3-2: Average Recurrence Intervals for different durations during March 2022 rain event

Site	Average Recurrence Interval (ARI) (years) for different durations during event											
	10 min	20 min	30 min	1 hour	2 hour	6 hour	12 hour	1 day	2 day	3 day	4 day	5 day
Fernside Station Telemetry Station	123	66	119	53	17	13	5	14	17	46	38	31
Hikuwai River at No4 Br	42	30	22	32	52	16	9	11	11	14	11	10
Hikuwai River at Willowflat	42	25	23	23	20	11	12	12	26	63	60	61
Mata River at Pouturu Br	16	27	37	54	30	64	19	17	25	36	25	19
Ruatoria Telemetry Station at Barry Ave	7	15	11	10	21	5	4	4	5	9	7	6
Te Puia	83	73	52	56	43	204	81	65	71	144	104	86

In addition to the very high 6-hour rainfall event recorded at Te Puia, the same 6-hour rainfall event recorded at Mata River (approx. 20km west of Tokomaru Bay) was found to have an ARI of 64 years. This difference in the ARIs for two rain gauges within 20km of each other shows that the rainfall intensity was temporally and spatially varied. The rainfall totals for the 3, 4 and 5 days leading up to the abutment washout are also shown to be very high for both rain gauges – ARIs of 60 years for Mata River and over 100-year for Te Puia. These high rainfall totals over the long duration would have created very saturated soils, potentially leading to high runoff rates during the high intensity rainfall events. The combination of these factors resulted in high rainfall and runoff in the catchment, which could have led to high water levels and flows within the Mangahauini Stream.

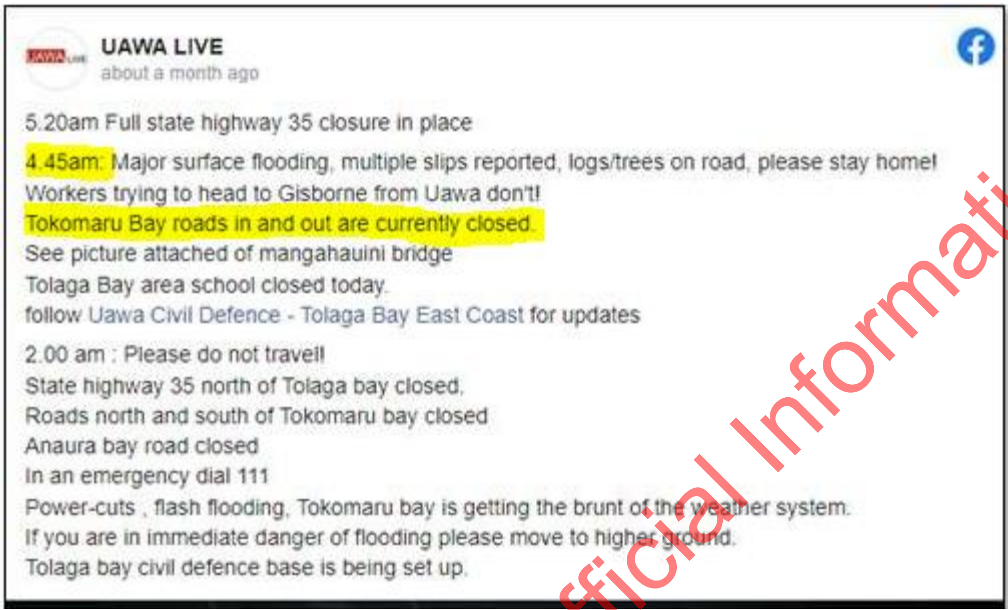
4 Lack of Resilience

Our changing climate is leading to patterns of increasingly extreme weather across the world, with more intensive rainfall leading to increasing frequency of flood events that have historically been considered lower return periods. This higher frequency of severe flooding is having a significant impact on structures in New Zealand. Bridges or culverts crossing, or retaining walls and other structures adjacent to rivers in flood are subject to scouring which can undermine existing protections and expose these structures to the risk of damage, particularly those with existing vulnerabilities. Damage to these structures increases the risks to road users and threatens critical service infrastructure. Increased engineering effort to enhance resilience would see Mangahauini No. 1 Bridge and other structures survive such events. For example, the use of bigger rock rip rap and groynes were applicable to divert the flows from vulnerable areas.

5 Tide Effects

Mangahauini No. 1 Bridge is located within 100m of the beach at Tokomaru Bay. As such, the river flow is affected by the sea tides. Towards high tide, the river would back up against the incoming sea, whereas during the tidal outflow, both the river and tidal flow would be in the same direction out to sea.

The Facebook snip below indicates Mangahauini No. 1 Bridge was closed at a 4.45am on the 23rd of March 2022.


UAWA LIVE
about a month ago

5.20am Full state highway 35 closure in place

4.45am: Major surface flooding, multiple slips reported, logs/trees on road, please stay home!
Workers trying to head to Gisborne from Uawa don't!
Tokomaru Bay roads in and out are currently closed.
See picture attached of mangahauini bridge
Tolaga Bay area school closed today.
follow Uawa Civil Defence - Tolaga Bay East Coast for updates

2.00 am : Please do not travel!
State highway 35 north of Tolaga bay closed.
Roads north and south of Tokomaru bay closed
Anaura bay road closed
In an emergency dial 111
Power-cuts , flash flooding, Tokomaru bay is getting the brunt of the weather system.
If you are in immediate danger of flooding please move to higher ground.
Tolaga bay civil defence base is being set up.

Figure 4-1: Facebook snip indicating Mangahauini No. 1 Bridge closed ~4.45am

Correlating the bridge closure timing with that of tide times at Tokomaru Bay as determined using the NIWA Tide Forecaster for the 22nd and 23rd March, you will see that the low tide on 23rd of March is roughly the same time the bridge was closed:

Date	Tide State	Tide Time	Tide Level (m)
Mar-22	High	10:00 AM	1.75
	Low	4.15 PM	0.21
	High	10.30 PM	1.76
Mar-23	Low	4.35 AM	0.26
	High	10.50 AM	1.75

Figure 4-2: Tide info for the 22nd and 23rd March 2022

Following a period of back-up of the flow at high tide at 10.30 pm on the 22nd of March the subsequent outgoing tide together with river flow in the same direction would have to significant drawdown effects past the bridge site, with increased flow velocities and the potential for scour to occur.

6 River Alignment

An aerial photo from March 2022 looking upstream (Figure 4-1) shows the main flow being under the southern 3 spans, indicating the remaining 3 spans on the north end of the bridge over land. This contrasts with the as-built drawing snip in Figure 1-1 above showing flow under the central 4 spans with the spans at either end over land. Also noticeable is a solid bank upstream of the bridge adjacent to the true left bank which is causing the flow to move over to the right bank; this flow direction partly being resisted by the old bridge abutment materials. The bank is shown circled in Figure 4-1 with a close up in Figure 4-2 showing that it is solid enough to take the weight of a digger.

Figure 5-1: Aerial upstream showing current flow alignment; also bank upstream (circled)

Figure 5-2: Close up of bank upstream, showing its solidity

7 Summary and Conclusions

WSP has determined 5 contributary causes for the washout of the southern bridge abutment. These include:

- Debris build up on bridge;
- The size of the rainfall event;
- Lack of resilience in the network;
- Tidal effects;
- River alignment.

We consider the first three causes, in no particular order – debris build up on the bridge reducing the waterway area to about two thirds of its normal width, the size of the rainfall event, determined as greater than 100 years Average Recurrence Interval for the 6 hourly duration in nearby Te Puia, and the lack of resilience in the network have been the three most significant causes of the washout of the southern abutment to Mangahauini No. 1 Bridge. As seen from the consequences of the recent March 2022 and previous such occurrences the network is vulnerable to natural events. Increased engineering effort to enhance resilience would see Mangahauini No. 1 Bridge and other structures survive such events

The two other causes of tidal effects and river alignment are considered to have had lesser influence on the abutment washout but are nonetheless contributary factors.

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