NIWA
Taihoro Nukurangi

NIWA Project: ELF17208

20 December 2016

Paulette Birchfield
West Coast Regional Council
PO Box 66
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Dear Paulette

Background

The township of Karamea is at risk of flooding from the Karamea River due to its location and a reduced level of protection due to aging flood-protection banks.

Between 2013 and 2015 the Karamea River migrated over 2 km south to exit via the Otumahana Estuary, and it appears to have continued its southward migration since then. The new location of the mouth appears to be causing additional back-up of floodwaters in some areas. The community have also raised concerns that continued southerly migration of the river mouth towards Kongahu may consume private property.

The West Coast Regional Council (WCRC) is seeking advice on whether there is any viable action (e.g., river mouth training walls, dredging or a stopbank extension as suggested by the community) that could be taken to restore and maintain the Karamea River mouth at its pre-2013 northerly location (in line with the township), whether any action should be undertaken, and what could be the likely consequences.

This letter provides that advice based on a brief investigation funded by an Envirolink Small Advice Grant (ref No 1743: C01X1630). The investigation included a site visit by Michael Allis and Murray Hicks from NIWA on 22November 2016 as well as examination of historical aerial photographs and documents provided by WCRC.

Site inspection

NIWA and WCRC performed an aerial inspection of the lower Karamea River, Otumahana Estuary, Kongahu Swamp and Granite Creek on 22nd November 2016 (10:30 am to 11 am). River flow was low at 90 m^3/s at the time and had been declining since a small flood that peaked at 1531 m^3/s 7 days prior (15th November). On 22 November, low tide was at 11:37 am for Karamea River mouth, offshore significant wave height was approximately 1.0 m from the west, and winds were light (< 10km/h) from the west.

During the site inspection the Karamea River and Otumahana Estuary had a single opening to the sea positioned 1 km from the southern extent of the estuary (Figure 1).

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Figure 1: Aerial oblique (view to southwest) of the Karamea River flowing past Karamea township (foreground), merging with the swamp overflow and Baker Creek (at right), before discharging into the Otumahana Estuary and exiting through the single southern opening to the Tasman Sea. [Source: M Allis, 22-11-2016]

River Floods

Flooding from the Karamea River threatens road access, buildings and agricultural land (Smart & Bind, 2010). Extreme flood flows for the river have been determined for a range of Annual Recurrence Interval (ARI). These are 100 year ARI = 3990 m^3/s, 50 year ARI = 3662 m^3/s, 20 year ARI = 3224 m^3/s, 10 year ARI 2885 m^3/s, 5 year ARI 2532 m^3/s and the "mean annual flood" (2.33 year ARI) = 2098 m^3/s .

Three notable recent river floods caused widespread inundation and property damage near the Karamea River. These were the November 1973 flood which was a 100 year ARI event (peak flow approximately 3950 m^3/s), the October 2013 flood which was a 22.5 year ARI event (peak flow 3279 m^3/s), and the October 1998 flood which was a 17.7 year ARI event (peak flow 3163 m^3/s). A 2d hydraulic model has been developed for the lower Karamea River based on the 1973 and 1998 events, and this replicated the widespread floodwaters and damage to infrastructure observed (Smart & Bind, 2010).

The river's present discharge point into the ocean is 3 km south from its most direct path to the sea (see Figure 1). This increases the flood risk to Karamea town because of the extra 'head' required for the river to flow the additional distance to the sea.

Floodwater from other sources also contributes to the flood hazard and backwater effect in the Estuary. Three rivers/creeks feed into the estuary system: Granite Creek and Blackwater Creek (draining Kongahu Swamp) at the southern extent, Baker Creek at the northern extent, along with the Karamea River and its overflow channels in the north. Also, a number of smaller creeks drain from South Terrace into the Otumahana Estuary from the east, through culverts beneath the Karamea Highway. The Karamea River is by far the largest contributor to hazardous flood events.

Figure 2: Location of known estuary openings. Year of observation with north (N) or south (S) shown if multiple openings visible. Symbols indicate approximate centreline of opening. [Source: Google Earth image Jan 2013].

River and estuary openings to the sea

The present Otumahana Estuary (Flagstaff Rd to Kongahu Village) is approximately 5.4 km long and is oriented north-south alongside the coastline. There is also geomorphic evidence of earlier shorelines, isolated swamps/lagoons and shoreline-cliffs which extend further north (250 m north of Golf Course Road) but were cut off by historic (c1929) river mouth training protection alongside Flagstaff Road. The total historic footprint of the estuary would have covered about 7 km when including the now cut off section. The extreme northern extent of this footprint also overlaps with the southern extent of the Oparara River mouth and estuary.

Historically, the Otumahana Estuary system has had either one or two openings to the sea which are expected to naturally traverse north and south along the coastline. Migration of estuary openings is generally in response to environmental changes to sediment fluxes (riverine and coastal), freshwater inflows, tidal exchanges, and offshore wave conditions (direction and height) - along with human intervention to any of these processes. The openings of the Karamea River and Otumahana Estuary provide typical examples of these processes, and the openings have occupied about a 4.5 km span of shoreline since records began. Figure 2 illustrates all known opening locations from available photographic and survey records. Figure 4 plots the opening locations as distance south from Flagstaff Road (which is the present northern limit of the estuary protected by a rock wall).

The following timeline of the openings and their locations provides context for the present issues and the wider historic changes to the river and estuary openings:

- The earliest available historic records are the 1912 and 1918 land surveys which show two openings to the sea: the river discharging north alongside Flagstaff Road (Carr, 2004), and a wide southern opening north of Kongahu.
- Major changes to the river opening followed the 1929 Murchison M7.8 earthquake. A landslide is reported to have dammed the upper Karamea River for a short period, and when the dam burst it sent a minor flood downriver (Carr, 2004). However, this and the other multiple landslides continued to supply sediment to the river which progressively silted up the river mouth to an unnavigable state (Furkert, 1932). Manual dredging of the river mouth was attempted to facilitate coastal shipping in the 1930s (Figure 3).
- Engineered river training walls and stop banks were subsequently constructed in the 1930s to protect the town and guide the river out to the north alongside Flagstaff Road. A gap was initially left in the wall at Maori Point to allow flood discharge into the Otumahana Estuary, but this has subsequently been infilled (Ministry of Works plan, 1937).
- From the 1940s to 1980 both estuary openings continued to migrate both north and south over much of the coastline. The Karamea River opening maintained a northerly position, with the Otumahana Estuary maintaining a position about 1-3 km south (Figure 4). Aerial photographs suggest that the two openings typically behaved predominantly as separate systems with a small degree of hydrodynamic coupling and water exchange between. By 1980 the openings had drawn close together to be separated by only 1 km.
- From 1980 to 2006 the estuary openings migrated south by about 1 km, maintaining a uniform 1 km separation.

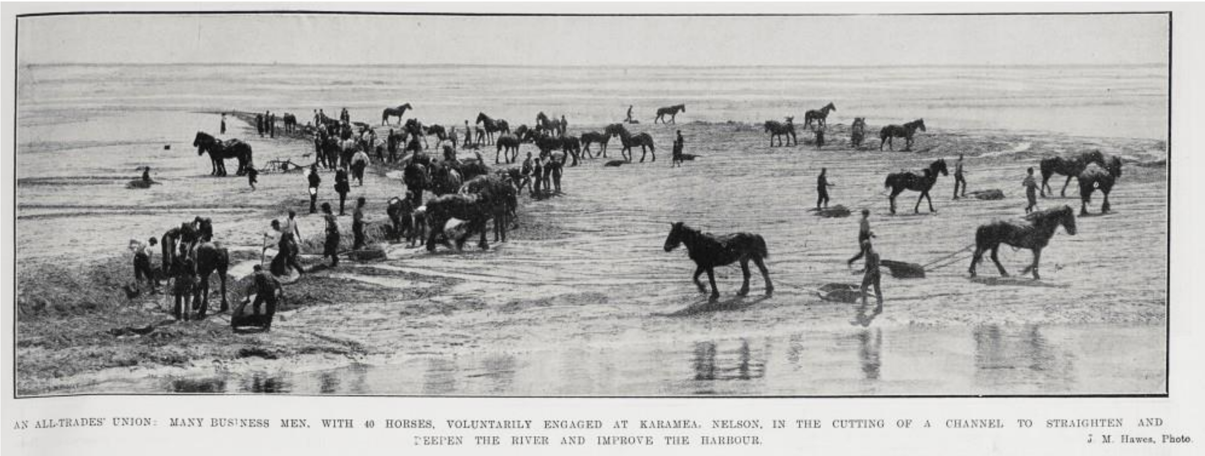

Figure 3: Attempts to straighten and deepen the Karamea River mouth c1930. [Photographer: J.M. Hawes, Source: Te Ara Encyclopaedia]

- During 2006 to 2008 the southern (estuary) opening migrated north and narrowed, while the northern (river) opening migrated south and widened. This indicates a further behaviour shift towards re-coupling of the river-estuary systems and preferential river and tidal discharge from the northern opening. The separation between openings was only 500 m in June 2008 (Figure 4).
- Between June 2008 and December 2010 the two estuary openings merged into a single opening for the first recorded time. The single opening was wider than historic openings (approximately 700 m wide) and was located at the site of the usual northern opening, with a direct (shortest path) outlet for the Karamea River (Figure 4).
- From December 2010 to 2014 the single opening migrated 1.2 km south towards Kongahu. Two large (approx. 20 year ARI) flood events occurred during this period (December 2011 and October 2013, both exceeding 3100 m^3/s discharge). It is unknown whether a second opening formed temporarily to discharge excess floodwaters.
- There was a brief period (several months) with two openings from November 2014. This was facilitated by mechanical excavation of a channel across the spit at the location of the previous northern opening (in line with township, 1.77 km from Flagstaff Rd – see Figure 4) and was followed by a 6.8 year ARI flood (2690 m^3/s). The new northerly opening was naturally infilled and closed in early 2015, probably because of a lack of summer flood flows to sustain the opening against wave-driven sand deposition.
- Sometime between March 2015 and March 2016 the single opening rapidly migrated south a further 1.5 km to its present location. A second mechanical cut was attempted over 12-13 May 2016. However, this was unsuccessful even when the river flow reached 2300 m^3/s (approx. 5 year ARI flood) the next week. Since this time there has only been a single opening, with the largest flood of 1700 m^3/s (less than the mean annual flood) unable to breach the sand spit – even in its mechanically weakened state.
- The present location of the opening, at 4.5 km from Flagstaff Road, is the southernmost position that has been observed. A further 1.5 km of southerly migration will begin to encroach on Kongahu village.

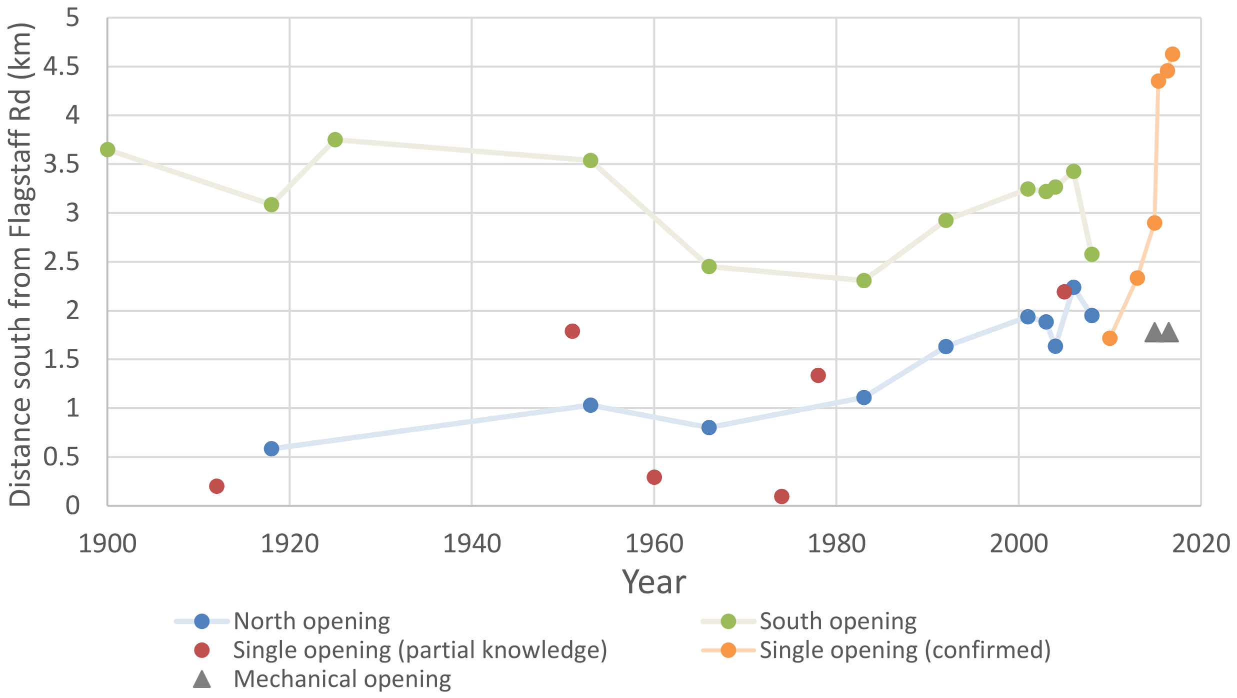

Figure 4: History of estuary opening locations as distance south from Flagstaff Road.

The present configuration of the river-estuary system has the Karamea River, guided by a rock training wall near Maori Point, spilling over a small estuarine delta into the Otumahana Estuary and being swept south behind the sand-spit (Figure 5). As the river flows over the delta it does not have a clear incised channel, indicating loss of current speed, allowing development of the delta through sedimentation processes. At the base of the delta the river collects into the southerly flowing estuary channel (Bakers Creek and the Overflow) behind the sand spit and follows a circuitous route for 3 km to the outlet near Kongahu.

The notch excavated during the May 2016 attempted mechanical opening remains (Figure 5), but shows evidence of infilling from both wave overwash and river sands. At its narrowest the spit separating the river and estuary is only 100 m wide with no vegetation.

Figure 5: Aerial oblique (view to east, upriver) of Karamea River discharging into Otumahana Estuary over an estuarine delta, merging with the swamp overflow and Baker Creek (from left), before flowing south behind the sand spit (foreground). [Source: M Allis, 22-11-2016]

The largest river discharge in the present configuration was 2300 m^3/s, with three separate smaller events with flows >1500 m^3/s. These have been unable to breach the sand spit at this location – even with mechanical assistance weakening the barrier (Figure 5).

Interpretation of physical processes

The slow alongshore migration of river and estuary openings is a natural response to the delicate balance of wave climate, sediment supply, tidal and river flows. The merging of two openings is also a natural process and depends on coupling and exchange between the tidal, estuary and river inflows. At Karamea from 2008 to 2010, the estuary (southern) opening migrated north slowly and was eventually absorbed by the river entrance which migrated south. The merging was enabled by increased coupling between the estuary and the ocean via the river opening, until this was the preferred opening. The southern entrance quickly silted up without sufficient maintenance flows to scour a channel. In the 1930s, Karamea engineers considered that forcibly decoupling the Karamea River and Otumahana Estuary with a training wall was a good idea to concentrate the river discharge and enhance natural scouring of the opening (Furkert, 1930s). However, this also caused additional flood hazards upstream as the rock training walls prevented flood flows from discharging and dispersing into the Otumahana Estuary.

The rapid southerly migration of the single opening (2014-2016) may be explained by a period of large northerly waves building a longshore bar parallel to the shoreline and across the river mouth during low river flows. When the opening discharges into the longshore trough (between bar and shoreline) it is directed alongshore and becomes trapped by subsequent onshore-migration of the bar. The time-history plots of Figure 4 suggest that the present location is an outlier (compared to all previous opening locations) and an unsustainable long-term opening location – especially with the circuitous route for the river.

The process of forming two openings is also a natural process of spit-breach during large flood flows. At Karamea, the river is expected to eventually breach the spit on its direct path to the sea. When this happens we expect that the southern opening should still remain at least in the immediate term by virtue of the large tidal area of the estuary. However until this time the river discharge will continue its circuitous route to the south, with associated higher flood hazard to Karamea Township. Evidence from recent flows and intervention attempts indicates that river flood discharges in the range 2300-2700 m^3/s are required to breach the spit providing some assistance is given by cutting a low point (or "fuse") in the spit. It is unclear what flood conditions are required to breach the spit without the aid of mechanical excavation, but these are expected to be larger again. A series of small floods following the breach are ideally required to scour and maintain a channel through the new opening. The southern opening would be expected to slowly reduce in size and maintain its present location if the northern opening remains a permanent opening.

Intervention options

Based on the above, we consider that the best way forward to relieve the enhanced flooding and erosion risks associated with the single, south-located outlet is to assist the Karamea River to breach the spit directly opposite the town.

Major engineering works have been employed in Karamea and the Otumahana Estuary since the 1920s, and there is a range of engineered interventions to assist the natural spit-breach process. These options are sketched in Figure 6 and include:

- Constructing river mouth training walls (as at Westport and Greymouth) to disconnect the river from the estuary and discharge straight to sea. This exercise would be very costly, with large scale changes to the estuary and beach, and would require a substantial dredging programme to maintain the entrance during non-flood conditions.
- Extend the existing left-bank stopbank/training wall which currently guides the river to its present location. However, this stopbank/wall previously extended approximately 50m from its current end point and was subsequently shortened by both the river (scour, collapse) and engineers because of the constriction and backing-up of flood flows. Re-extending the training wall would cause the same problem.
- Construct a series of short stub-groynes at 45 degrees to the river flow direction to enhance river channelization across the present estuarine delta during low flows, and therefore direct the force of the river discharge directly into, and hopefully through, the sand spit. This would require smaller rock quantities than a large scale training walls, but would act to slow floodwaters and potentially increase flooding hazard through the backing-up of water prior to the sea outlet.
- Construct permeable and temporary (25 year lifespan) wooden training walls to partially direct the flow through the estuarine delta in a more direct path to the sea, in essence extending the present training wall arc. This would be relatively costly, with similar drawbacks to other engineering measures, but could be removed more easily if unintended consequences eventuate.

- Dredging a new channel through the estuarine delta and spit. This would only be a temporary measure as the river base flows are unable to maintain a northern opening.

There are other variations and combinations of temporary and permanent engineering approaches to managing the present situation. However, all of these major works have substantial costs, environmental drawbacks, and potentially unforeseen (and irreversible) consequences.

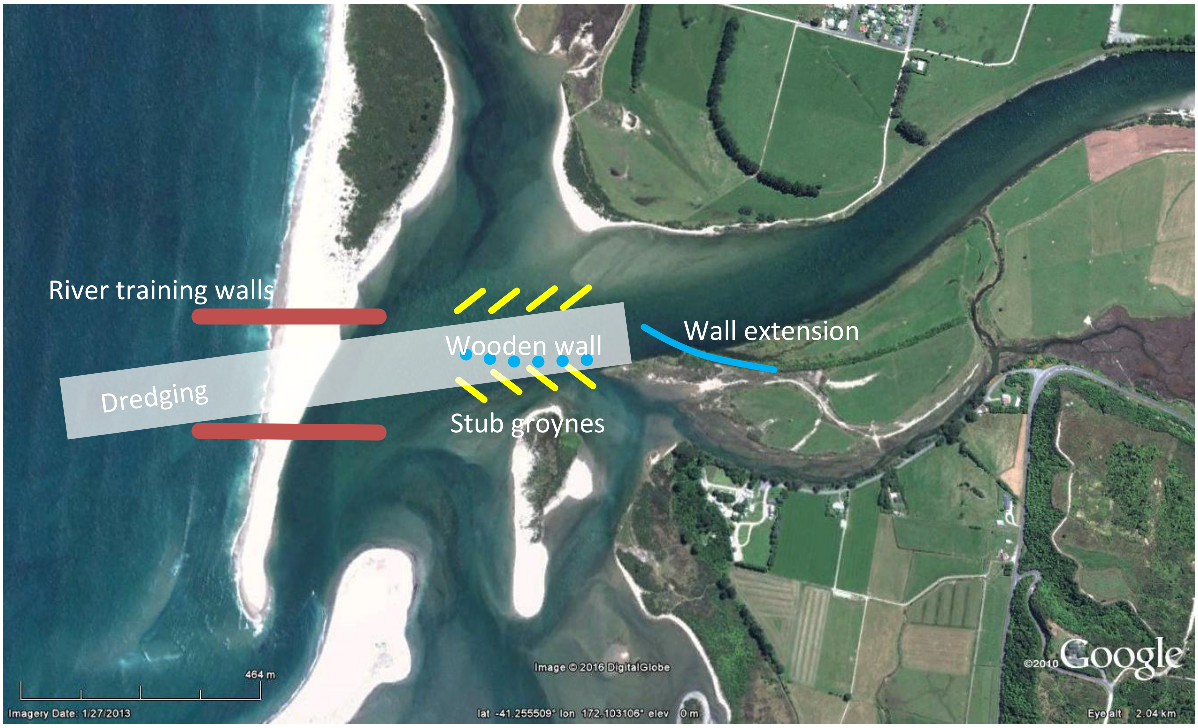

Figure 6: **Major engineering options at Karamea.** [Background image: Google Earth, 2013]

At Karamea, minor engineering works are more appropriate to manage both ordinary and flood flows. These are better suited to work with the natural processes, with the understanding that they may only be temporarily successful, and may need repeating several times but are less costly.

We recommend to mechanically excavate a breach channel for the floodwater to overwhelm and widen the opening. We recommend to prepare in readiness and maintain 2 or 3 channels through the sand spit at similar locations as the historic river mouth openings, oriented as shown in Figure 7. The prepared breach channels should be maintained after each minor unsuccessful flood event to ensure viability after flood/wave/wind sand deposits infilling. The key concept is to await a major river flood to push the river through the pre-weakened spit breaches. It is expected that a flood discharge greater than 2300 m^3/s (approximately a 5 year ARI flood event) will be required to breach the pre-weakened openings. The preparation of multiple channels is a reflection of the uncertainty of how/where the river will scour a channel through the estuarine delta during flood flows, and therefore ensures that the spit is pre-weakened in several locations to increase the chances of a major breach and a more permanent opening eventuating.

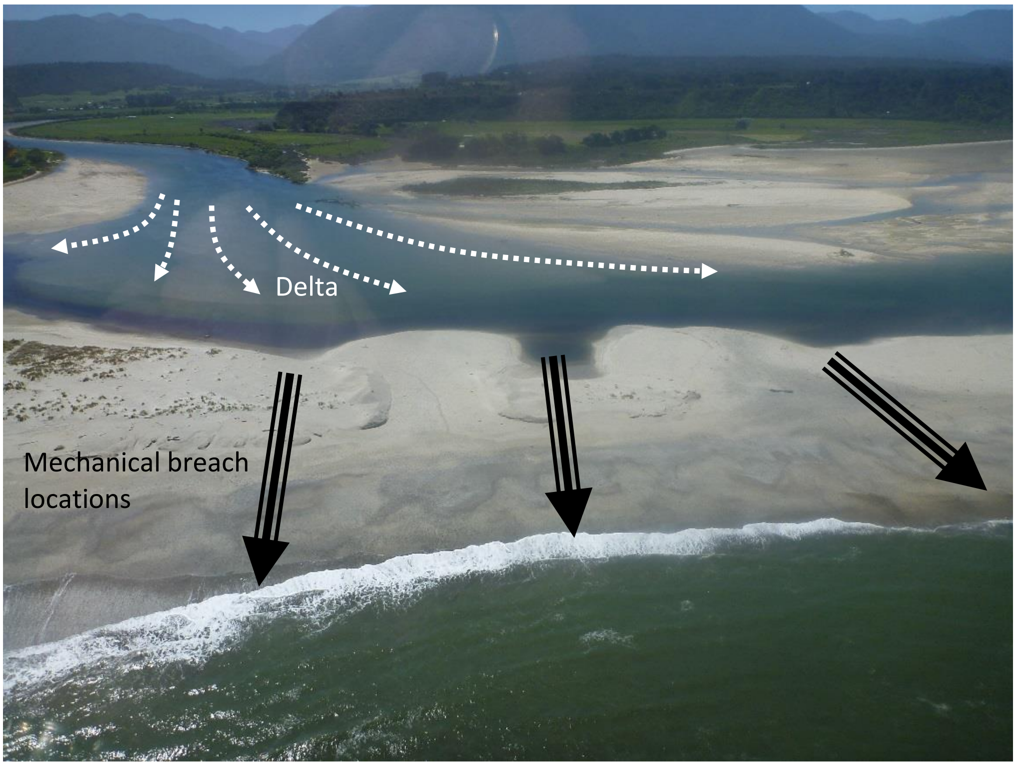

Figure 7: Mechanical channel breach locations for Karamea River.

This new opening is expected to close up again unless a sequence of flood flows maintain and deepen the new channel opening. Shortly after the closure next occurs, the spit should again be excavated in several locations in preparation for the next flood to breach the spit. If this occurs repeatedly, a detailed investigation may be required to refine configuration and position of the excavated channel and to predict the longevity of the opening.

Conclusions and recommendation

The flood risk to Karamea Township has increased because of the location of the present estuary/river opening to the sea, with the river flowing behind a narrow sand spit to discharge 3 km south of the town. The extreme southern location of the present opening is unprecedented in recorded history, and is considered an unsustainable long-term location from the viewpoint of those at risk from its effects. Natural processes are expected to eventually breach the sand spit during large floods, creating a direct route for the floodwater to escape near the town. However flood flows up to 2300 m^3/s have been unable to create this breach, even with a mechanical preparation of a new opening location.

The recommended management of this heightened risk is to continue as present by anticipating a large flood flow and mechanically excavate a channel through the spit for the floodwater to overwhelm and widen. Maintaining 2 or 3 narrow channels through the spit in readiness for such an event would increase the chances of a successful permanent opening (Figure 7). It is expected that a flood discharge greater than 2300 m^3/s (approximately a 5 year ARI flood event) will be required to breach the pre-weakened openings. This new opening is expected to close up again unless a sequence of flood flows maintain and deepen the new channel opening.

If this mechanically-assisted opening followed by natural closure of this opening occurs repeatedly, a detailed investigation may be required to refine configuration and position of the excavated channel and to predict the longevity of the opening.

If WCRC and the Karamea community consider that waiting for a flood large enough to breach the weakened spit is an unacceptable uncertainty and risk, more detailed investigations of major and minor engineering options may be performed using numerical modelling – extending the NIWA 2010 models (Smart and Bind, 2010). This would be a costly modelling exercise, but would allow for more detailed guidance on intervention works including identifying unwanted side-effects.

Yours sincerely

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Reviewed by:

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Approved by:

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Project Director

References

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